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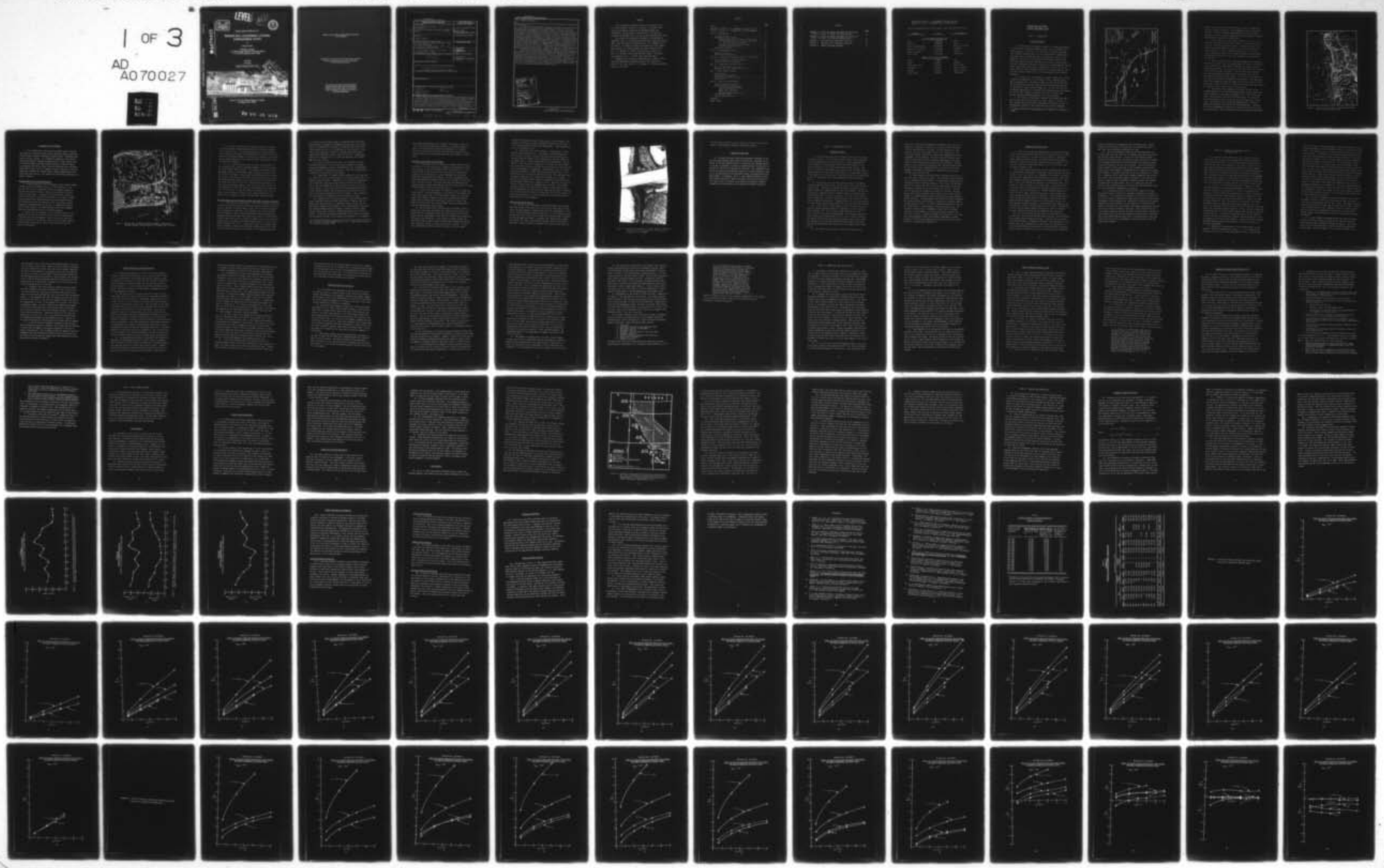

M. P. HL-79-4 MISSION BAY, CALIFORNIA, LITTORAL COMPARTMENT STUDY APRIL 1979

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MISSION BAY, CALIFORNIA, LITTORAL COMPARTMENT STUDY

by

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Four separate and distinct major problems exist at Mission Bay proper at the present time, with an additional beach erosion and bluff collapse condition occurring at Sunset Cliffs. The major problems at the Bay include: (a) a dangerous condition at the jettied entrance produced by frequent breaking waves, (b) short period waves of excessive height attacking moored boat areas in Quivira Basin, (c) long period seiche or surge in Quivira Basin and other locations within Mission Bay, and (d) a complete closure of the exit of the San
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20. ABSTRACT (Continued).

Cont

Diego River Floodway by littoral material being trapped between the middle and south jetties.

In order to provide long-term (permanent) solutions to the four principal problems which exist at Mission Bay, knowledge of the amount of littoral material which is moving past the entrance channel to the Bay is required, along with an understanding of the monthly occurrence of this flow of material by direction. This information will be used to evaluate the potential effects of littoral transport, beach scour, and deposition on the functional design of proposed structural improvements. The latest statistical wave data for this region were applied to ascertain an estimation of potential longshore transport of littoral material for proposed alternative solutions. It was found that the Mission Bay Littoral Compartment, on a net movement basis, is essentially in a state of dynamic equilibrium. The approximately 20,000 cu yd estimate of net northerly transport of material is probably not within present ability to discriminate, based upon the accuracy of the methods and the procedures used to develop the wave statistical data. On the other hand, the average wave climate has the potential for moving large quantities of material on a gross basis.

Several different structural alternatives have been proposed for evaluation to provide an optimum solution to the major problems presently existing at Mission Bay. Most of these alternatives would have a definite effect on the littoral regime of the region, and these effects are extremely difficult to hypothesize from analytical considerations. The appropriate theoretical work necessary to provide computational schemes for the solution of the effects of structural improvements in the littoral zone has not been developed at this time. Due to the complexity of the problem, the only viable method of analyzing the efficacy of alternative proposed structural improvements for Mission Bay is with a three-dimensional physical hydraulic model.

PREFACE

The investigation reported herein was requested by the U. S. Army Engineer District, Los Angeles, in December 1976, and was subsequently authorized by Intra-Army Order for reimbursable services dated 6 January 1977. The study was initiated in September 1977, and was up-dated through March 1979.

This study was performed by personnel of the Hydraulics Laboratory (HL), U. S. Army Engineer Waterways Experiment Station (WES), under the general direction of Mr. H. B. Simmons, Chief, HL, and Dr. R. W. Whalin, Chief, Wave Dynamics Division (WDD). Data analysis was conducted under the direct supervision of Mr. C. E. Chatham, Jr., Chief, Wave Processes Branch, and Mr. D. D. Davidson, Chief, Wave Research Branch. The report was prepared by Dr. L. Z. Hales, Wave Research Branch.

Commanders and Directors of WES during the conduct of this study and preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) AND METRIC (SI) TO U. S. CUSTOMARY UNITS OF MEASUREMENTS

Units of measurement used in this report can be converted as follows:

Multiply	By	To Obtain
	U. S. Customary to Metric (SI)	
feet	0.30480000	metres
fathoms	1.82880000	metres
knots (international)	0.51444440	metres per second
miles (U. S. statute)	1.60934400	kilometres
degrees (angular)	0.01745329	radians
cubic yards	0.76511000	cubic metres
	Metric (SI) to U. S. Customary	
metres	3.280839	feet
metres	0.546807	fathoms
metres per second	1.943845	knots (int.)
kilometres	0.621371	miles (statute)
radians	57.295788	degrees (ang.)
cubic metres	1.307002	cubic yards

MISSION BAY, CALIFORNIA, LITTORAL COMPARTMENT STUDY

PART I: INTRODUCTION

Project Location

1. The Mission Bay, California, region is located approximately 10 miles* north of San Diego Harbor on the coast of southern California, Figure 1. This area is so distinctly isolated by northern and southern headlands, and is of such limited extent (approximately ten miles) that it really need not be considered a littoral cell. Bounded by the rocky La Jolla headland on the north and the Point Loma rock ridge which rises 400 feet on the south, the Mission Bay Littoral Compartment effectively separates two well-documented littoral cells, those being the Oceanside, California, Littoral Cell on the north which has a net southerly transport of littoral material, and the Silver Strand Littoral Cell on the south with its net northerly transport.

2. A littoral cell is defined as a coastal segment that contains a complete sedimentation cycle including sources, transport paths, and an ultimate sink. The Silver Strand Littoral Cell extends from the Tijuana Lagoon northward along the Silver Strand and terminates at the entrance channel into San Diego Bay. The sink for this cell is offshore deposition by strong ebb tidal currents which flow through the bay entrance channel, according to the work of Inman,[1] and prevents further northward transport of littoral material.

3. The Oceanside, California, Littoral Cell extends from Dana Point on the north to La Jolla on the south. There is little, if any, evidence of littoral drift around Dana Point; however, there is considerable evidence of sand losses down the La Jolla submarine

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* A table of factors for converting units of measure is presented on page 4.

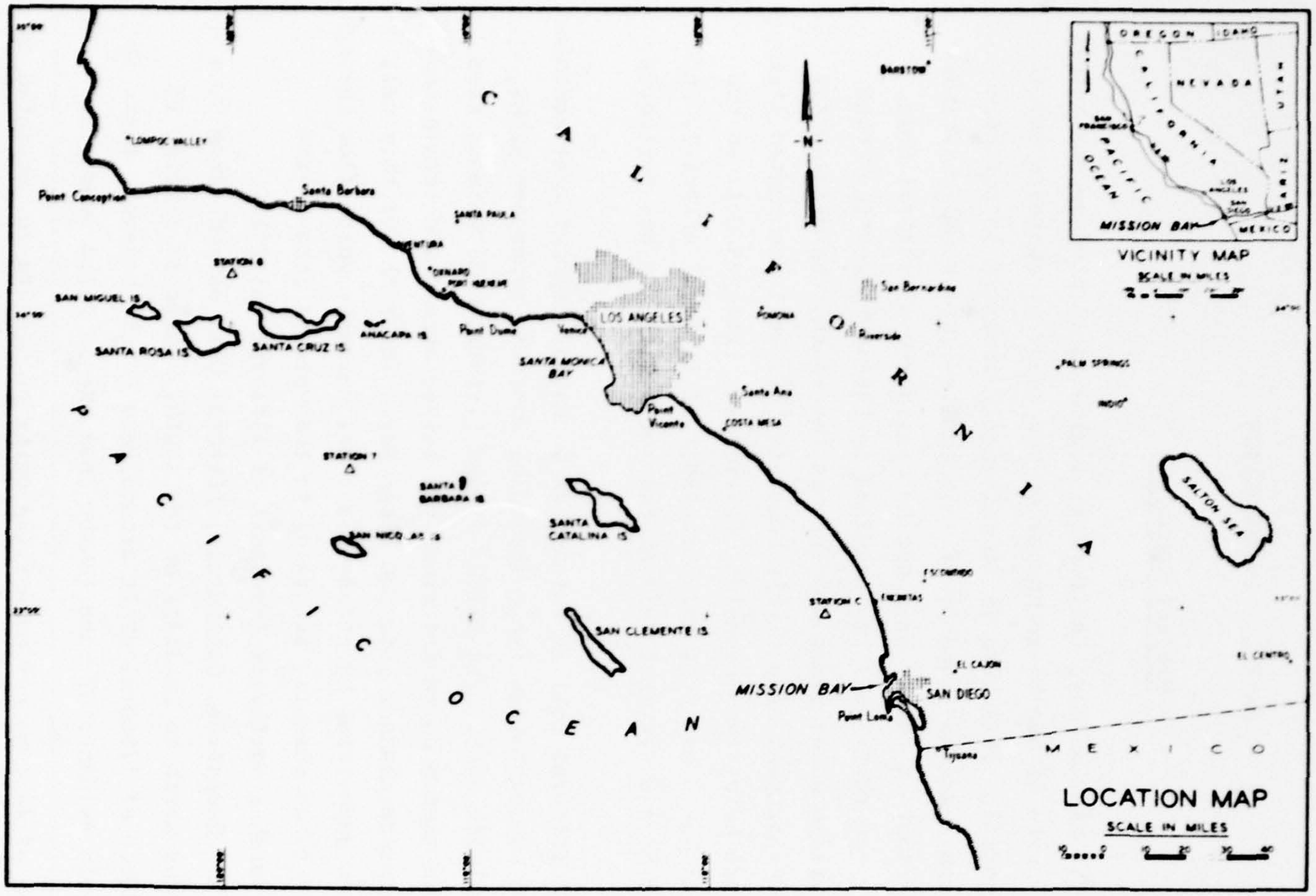

Figure 1. Project Location, Mission Bay, California, Littoral Compartment.

canyon, as this region has been intensively studied by Inman[2] and others at Scripps Institution of Oceanography, which is located in La Jolla. La Jolla submarine canyon appears to be the southern terminus of the net southerly transport of littoral material through the Oceanside, California, Littoral Cell.

4. Mission Bay is a tidal lagoon situated in the City of San Diego and separated from the Pacific Ocean by a broad two-mile-long sand spit called Mission Beach, Figure 2. The bay occupies a rectangular area approximately two miles on a side and was formerly called False Bay. It was originally connected to the ocean by a shallow unprotected inlet at the southern terminal of Mission Beach. The municipality of Pacific Beach lies adjacent to, and north of Mission Bay.

5. South of the inlet the Ocean Beach segment of the shoreline consists of a broad sandy beach approximately 0.6 mile in length which extends downcoast to rocky bluffs which mark the beginning of the Point Loma peninsula. This region has been subjected to many alternate periods of erosion and accretion. Local interests have requested the Corps of Engineers to make beach erosion studies of specific problem areas within San Diego County. One of the areas studied was the shoreline fronting the community of Ocean Beach. This particular project was completed during the summer of 1955 and consisted of the placement of about 275,000 cu yd of beach fill dredged from the Mission Bay project, and the construction of a stone groin.

6. The Sunset Cliffs segment of the region consists of the northern portion of the Point Loma peninsula and extends from Niagara Avenue southward to the southern boundary of the city of San Diego, about 3 miles upcoast from the tip of Point Loma. The erosion of the beach and the cliffs in this area has been progressive for many years. The retreat of the bluffs has damaged public streets and destroyed both public and private land and improvements. On-going studies are attempting to quantify the causes and rates of the beach and bluff erosion, and will develop alternative plans for restoration.

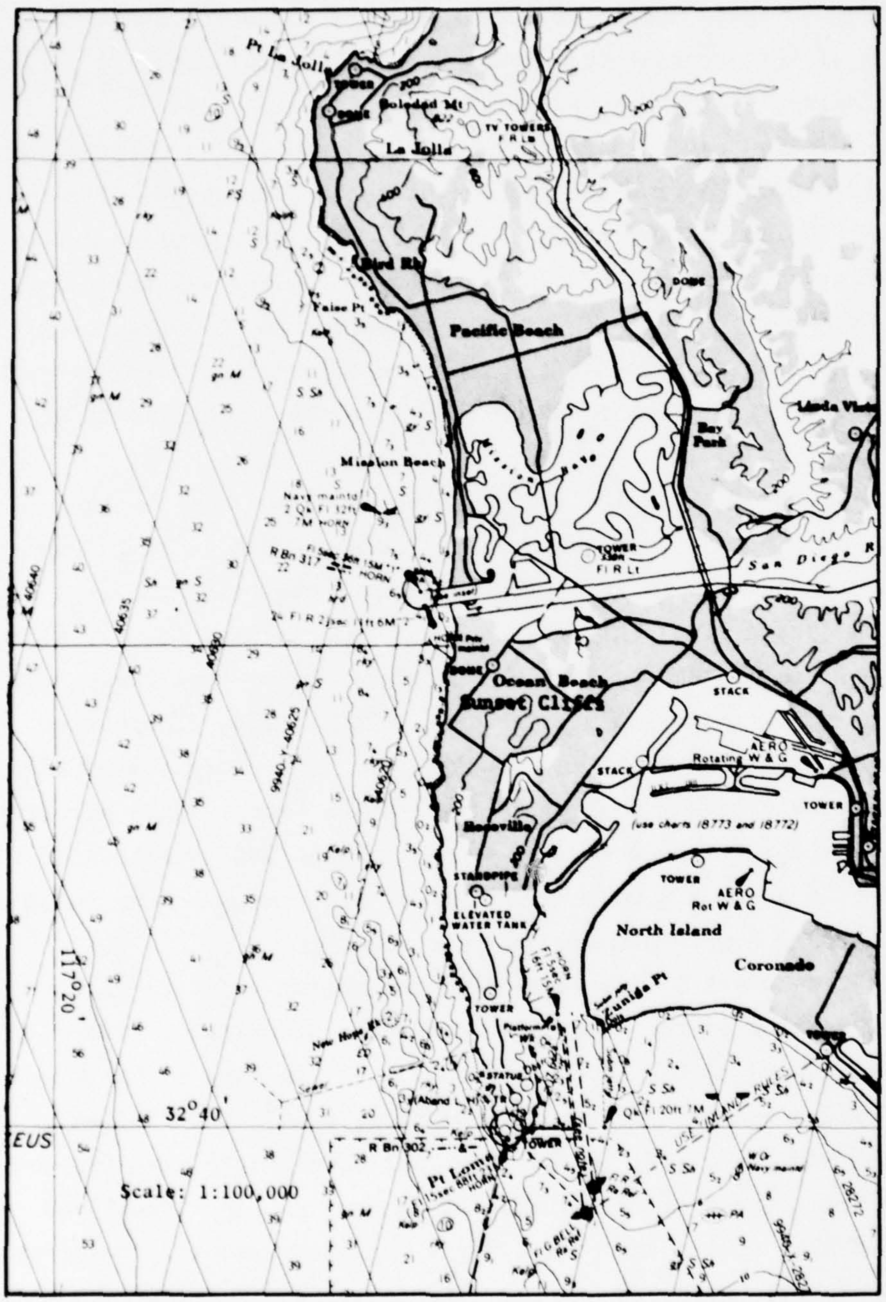

Figure 2. Mission Bay, California, Littoral Compartment, Point La Jolla to Point Loma.

Statements of the Problems

7. Four separate and distinct major problems exist at Mission Bay proper at the present time, with an additional beach erosion and bluff collapse condition occurring at Sunset Cliffs. The major problems at the Bay include: (a) a dangerous condition at the jettied entrance produced by frequent breaking waves, (b) short period waves of excessive height attacking moored boat areas in Quivira Basin, (c) long period seiche or surge in Quivira Basin and other locations within Mission Bay, and (d) a complete closure of the exit of the San Diego River Floodway by littoral material being trapped between the middle and south jetties. The location of these four problem areas is shown in Figure 3.

Breaking Waves at the Jettied Entrance

8. During the period of the development of the entrance channel between the north and middle jetties, in the mid-1950's, it was observed that, all too frequently, waves were either breaking in the entrance channel or were so steep as to constitute a serious hazard to small boats. Lifeguards at the Mission Bay channel entrance station kept a log of the conditions at the channel entrance during daylight hours which pertained to days during which waves were observed to break over half-way across the entrance channel throughout a greater portion of the day. A summary of their log listed 43 days during a six month period in which waves commonly broke more than half-way across the entrance channel.

9. Records of the capsizings in the entrance channel are incomplete due to the fact that many rescues have been accomplished by persons other than lifeguards. Only in the case of fatalities is there certain to be an official record of the accident; however, many non-fatal capsizings are known to have occurred since the project construction.

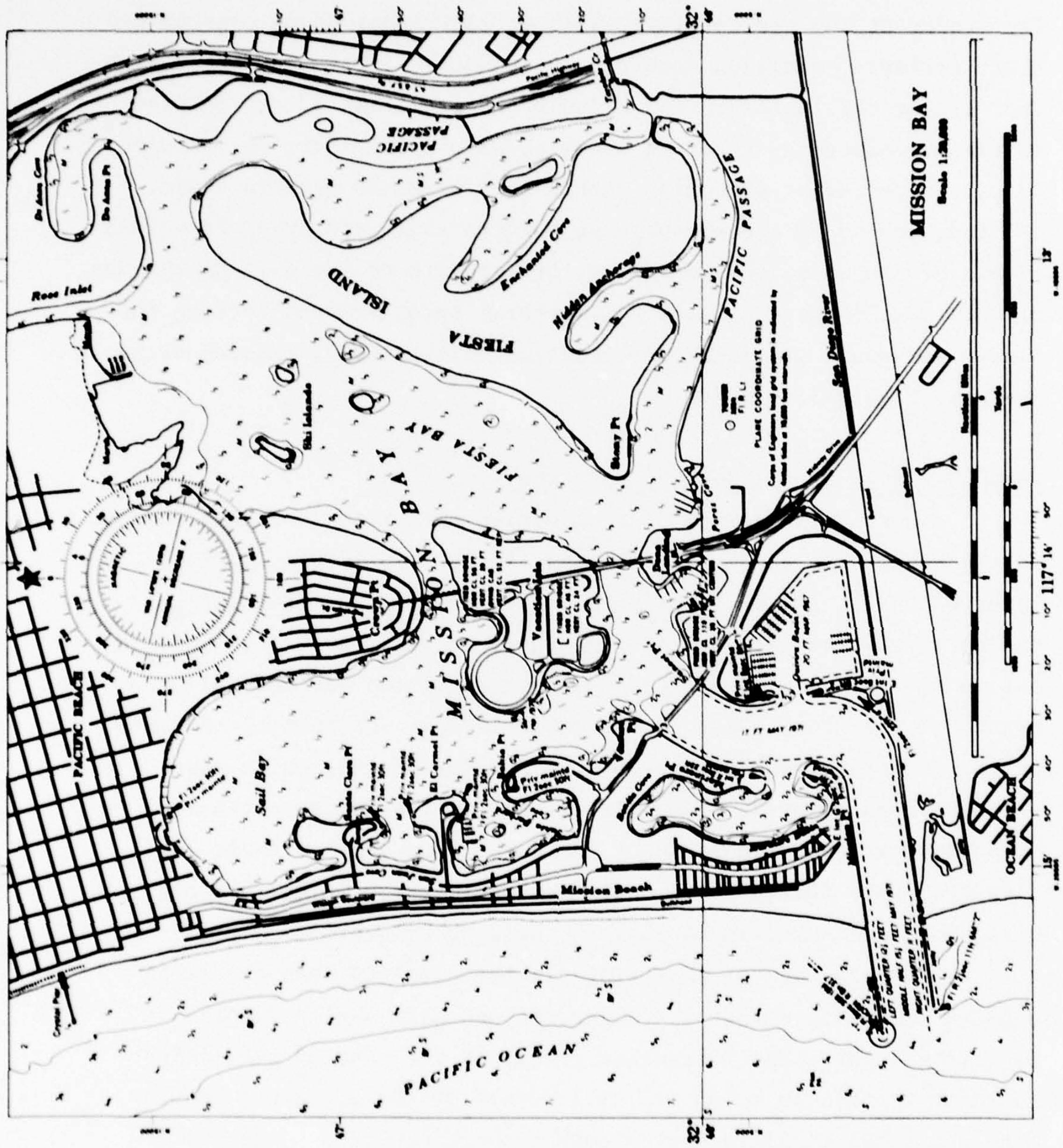

Figure 3. Mission Bay, California, Entrance Channel, Quivira and Mariners Basins, and Sand Block of San Diego River Floodway.

10. The precise reason for the common occurrence of breakers across the entrance channel during periods of flood and slackwater is not entirely clear. The tripping mechanism for the breaking of the waves must be associated with shoaling off the middle jetty, but because of the great frequency of breakers, particularly in the winter season, good soundings are not always available simultaneously with the rough surf condition.

11. It is readily observed that the waves peak and break off of the middle jetty, and once breaking commences it continues along the crest toward the north jetty. If the waves which break off of the middle jetty are sufficiently large, breaking continues all the way across the entrance. Large waves have been observed to be breaking as far as 100 yards off the middle jetty and the breaking continues northward along the wave crest, until finally the wave breaks on the north jetty after the crest has traveled some considerable distance into the entrance channel. Waves often continue to break several hundred feet inside the channel with heights at times estimated to be 14 ft or more. Strong ebb currents are probably the cause of much of this disturbance; however, these large breaking waves are believed to be related to 4 and 5 ft high surges in Quivira Basin.

Wave and Surge Activity in Quivira Basin and Other Locations in the Bay

12. The entrance to Mission Bay is exposed to wind waves and swell from all the westerly deep-water directions between northwest and south. The wide entrance to the Bay admits a great deal of wave energy which must be absorbed or reflected. Wave problems exist in the two deep-water anchorages of Quivira Basin and Mariners Basin when high waves propagate down the entrance channel and, particularly in Quivira Basin, reflect from the basin walls. Wind wave damages occur to the boats and floating docks when waves with heights greater than 1/2 ft exist with periods between 8 and 16 sec. Long period swell is exceedingly difficult to eliminate, and the arriving swell conditions may excite surge or seiche activity which also contributes to the damaging potential.

If a portion of the evident seiche is generated within the harbor through energy exchanges from undamped entering swell, any features added to the harbor for the purpose of reducing short period wave energy should also assist in a reduction of seiche activity. However, if the seiching is caused by incident long period energy, modifications designed to reduce swell may not have a significant impact on seiching and could, in some circumstances, even further aggravate the seiching.

13. Losses in Quivira Basin alone are estimated to exceed $1,000,000 per year in loss of rental fees, limitations on recreational and commercial activity, reduced public use, reduced employment, and delays in construction activity. The City of San Diego is estimated to be losing 20% of this amount.

14. Observations by Seymour* during December 1977 of surge and wave activity in Mission Bay revealed 1 to 2 ft high waves with 15 sec periods in Quivira Basin. Superposed on this wave was a combination cross basin and a long basin surge with a period on the order of 100 sec and an accompanying run-up of about 3 ft vertical excursion on the rip-rap. At this time waves were breaking over both jetties at the entrance channel, and the harbor patrol warned boaters that waves were breaking completely across the channel. These conditions were described by the dockmaster as about as bad as it gets.

15. Regardless of the origin and type of waves entering Quivira Basin, and other locations within Mission Bay, it appears that hazardous wave conditions exist a substantial portion of the time in the entrance channel and a decrease in this energy would be desirable. Wave energy propagates down the channel, reflects from the curved channel section, and penetrates through the openings to the various basins. The beaches in Mariners Basin appear to be effective in damping considerable amounts of wave energy, and therefore it is important

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*R. J. Seymour, Personnal Communication to U. S. Army Engineer District, Los Angeles, 05 January 1978.

that future developments do not eliminate the beaches in favor of a less efficient wave absorbing structure. Any proposed plans to alter the existing beaches should be accompanied by a careful analysis of their wave absorbing characteristics, and provisions should be made to provide equally efficient wave absorbers in their place.

Blockage of San Diego River Floodway

16. Mission Bay, prior to 1946, was a natural estuary of over 4,000 acres. The San Diego River originally discharged into either San Diego Bay or into the southeast corner of Mission Bay. It was realized that if the San Diego River were allowed to continue to discharge into San Diego Bay, serious shoaling would result and commercial shipping would be hindered. In 1876 a permanent levee was constructed which permitted the river to discharge its silt and debris into Mission Bay. The resulting tidal prism maintained an estuary entrance channel approximately 200 ft wide and about 8 ft deep, connecting Mission Bay with the Pacific Ocean.

17. Coastal San Diego County is subject to rare but sudden and severe floods. From the headwaters to the mouths of the canyons, the streams have steep slopes. From the steeper canyons to the Pacific Ocean, the streams are flatter as they pass through broad valleys. These flatter channels have insufficient capacity to carry large floods with the result that, during floods, streams overflow their banks and innundate the valley plains.

18. The San Diego River and Mission Bay, California, Project, authorized by the River and Harbor Act, approved 24 July 1946, was a project for the improvement of the lower San Diego River for flood control and the improvement of Mission Bay for small-craft navigation. The project plan called for a river channel contained between two levees about 900 ft apart, which would penetrate through the littoral zone as parallel jetties to stabilize the river location. A third jetty approximately 900 ft north of the north river jetty would

stabilize the entrance channel to Mission Bay, and the middle jetty (common to both projects) would completely separate the San Diego River Floodway from the Mission Bay improvements. These engineering works were completed in 1953.

19. The south jetty of the floodway is approximately 1,700 ft shorter than the middle jetty. Consequently, north-flowing long-shore littoral currents carrying sand from Ocean Beach meet an obstruction and the sediment load is deposited in the wave shadow of the middle jetty, or across the mouth of the flood channel. The net effect is that the entire floodway exit is blocked by sand to about the +10 ft MLLW elevation, and thus the effectiveness of the San Diego River flood channel is compromised. Uncertainties exist as to what would be the effect of a major flood on the San Diego River, as the flood waters try to exit into the Pacific Ocean. The sand plug shown in Figure 4 might wash out, freeing the floodway for its design purpose, or backwater effects might cause ponding of the flood waters and innundate residential or commercial areas. Questions arise as to the most effective means of combating this situation. For example, instead of removing the entire plug, perhaps a pilot channel would assist floodwaters in scouring out the remaining sand block. Additionally, measures should be taken to insure that the sand fillet does not return if, indeed, it is a serious impediment to the flood capacity characteristics of the floodway.

Sunset Cliffs Beach Erosion

20. Erosion of the shoreline in the Sunset Cliffs area of Ocean Beach has become increasingly more serious to the home-owners and has caused increased damage to both private and public improvements. Erosion is occurring from two separate processes: (1) wave induced erosion at the base of the cliffs, and (2) bluff top erosion because of surface run-off and human activities. In general, the shoreline has changed very little since 1952, although deterioration of the sand beach has continued. Surveys indicate an average cliff retreat on the order of

Figure 4. Sand Plug Consisting of Littoral Material Completely Blocking Exit of San Diego River Floodway to an Elevation of +10 ft MLLW.

1 ft per year in the most critical section, with this critical area gradually encroaching on adjacent susceptibile regions.

Purpose of the Study

21. In order to provide long-term (permanent) solutions to the four principal problems which exist at Mission Bay, knowledge of the amount of littoral material which is moving past the entrance channel to the Bay is required, along with an understanding of the monthly occurrence of this flow of material by direction. This information will be used to evaluate the potential effects of littoral transport, beach scour, and deposition on the functional design of proposed structural improvements. Accordingly, the U. S. Army Engineer Waterways Experiment Station was asked to apply the latest statistical wave data for this region, and to ascertain an estimation of potential longshore transport of littoral material for proposed alternative solutions.

PART II: PHYSIOGRAPHIC SETTING

Geologic Evolution

22. The San Diego region may be divided from west to east into two major sections: (1) an elevated coastal plain section characterized by prominent marine wave-cut terraces, locally interrupted by stream channels conveying water from the eastern highlands to the Pacific Ocean; and (2) a dissected mountain-valley section. This area lies within the Peninsular Range Province, one of eleven physiographic provinces of the State of California. This geomorphic province is developed on an extensive fault block that occupies the southwestern portion of California and extends southward into Baja California, Mexico.

23. On the whole, the San Diego region presents an asymmetric transverse profile having a long, gentle western slope and a steeper eastern slope. Highlands are present toward the east and the topography becomes less rugged toward the west and southwest. On the east, the region is separated from the Colorado Desert by steep mountains ranging from 3,000 to 6,000 ft in height. The Coastal Plain section, which is underlain by Tertiary marine sediments with a relatively thin cover of Quaternary deposits, is characterized by a series of dissected wave-cut terraces which extend inland from the coast for about ten miles.

24. In the vicinity of San Diego, a series of terraces has been formed on gently dipping sediments of Cretaceous, Eocene, Pliocene, and Pleistocene age. These terraces range from near sea level to about 1,200 ft in elevation, although many of the surface features of these terraces have been modified or destroyed by extensive erosion. The Coastal Plain section has been dissected by various rivers which have formed a series of flat-bottomed alluvium-filled valleys that provide important ground water reservoirs, for example the San Diego River.

25. The Coastal Plain section of the Pacific drainage area

consists of both marine and nonmarine sedimentary deposits of conglomerates, sandstones, siltstones, and shales of the Cretaceous, Tertiary and Quanternary Divisions. In late Cretaceous or early Tertiary time, San Diego County was part of a peneplain, a low-lying body of land so reduced by erosion that comparatively little topographic relief remained. A period of uplift followed, accompanied by faulting and folding, forming high mountains along the eastern section and partially breaking up the peneplain. Streams began to carve the present drainage system, and the present relief of the Coastal Plain is apparently due to several cycles of submergence and elevation inaugurated in middle Tertiary time and continuing until Recent time.

26. Recent deposits of fossiliferous sand and loam occur all along the shore of San Diego County. The configuration of the shoreline of southern San Diego County is irregular due to differences in geological structure and rock hardness. At La Jolla, the shoreline projects out about a mile due to the resistant nature of the hard Cretaceous sandstones which outcrop there at sea level. Between Pacific Beach and the entrance to Mission Bay, the less resistant Eocene and Pliocene sediments have yielded to wave attack and this feature, in combination with a local structural low, has produced a mature shoreline. A long sandspit south of Pacific Beach, separating Mission Bay and the Pacific Ocean, is underlain by numerous cobbles at about mean sea level. All of the lowland between Mission Bay and San Diego Harbor is a delta deposit of the San Diego River. The shoreline of Point Loma is irregular in detail due to the hard Cretaceous rocks exposed at sea level and closely resembles the shore near La Jolla. Extensive geologic investigations of this area have been performed by State of California, Department of Water Resources,[3] and have been reported by beach erosion control studies of the U. S. Army Corps of Engineers.[4]

Hydrologic Characteristics

27. While the mean seasonal precipitation of coastal San Diego County varies with elevation from about 10 in along the coast to about 35 in in the mountains, the region is still subject to infrequent though sudden and severe floods. The precipitation exhibits great seasonal fluctuations, and storm intensity also varies greatly. The storm of record for the San Diego River is 10.37 in in 24 hrs, and occurred in Feburary, 1927.

28. The San Diego River drains an area of approximately 435 sq mi, of which 88% are mountainous highlands. Most of the year the lower reaches of the river are dry as a consequence of two major reservoirs, and during the summer months the headwaters are also dry. The river flows southwest through the mountains to El Capitan Reservoir. From here it flows west through the urbanized area of Lakeside where it is joined by a major tributary, San Vicente Creek. The waters of the San Vicente Creek are retained by San Vicente Reservoir prior to its confluence with the San Diego River. Between Lakeside and Mission Gorge, the river (again called San Diego River) flows through low lying and rapidly growing Santee, California. From the upper Mission Valley through the lower portion of the Valley, where the greatest urbanization and commercialization of the flood plain occurs, the river gradient decreases rapidly. The relatively flat channel of the San Diego River from El Capitan Reservoir to the ocean is insufficient to carry large discharges during flood periods, and the resultant discharge overflows the channel and innundates the flood plain.

29. At the west end of Mission Valley the San Diego River is diverted into the rock-lined San Diego River Floodway, thus preventing its discharge from entering Mission Bay. Since the exit of the San Diego River Floodway is completely blocked by littoral material at the present time, the consequences of a major flood are uncertain, as it is not known whether the sand plug will erode and permit the passage of flood water, or whether it will act as a dam and cause ponding and

backwater innundation of commercial and residential areas. Severe floods have not occurred in recent years, as evidenced by Table 1, and, thus, their likelihood increases with time.

30. The first documented flooding of the San Diego River was in 1825, when the river silted in its channel and changed course from Mission Bay to San Diego Bay. In 1862 the river had its largest historical flood flow with a discharge of nearly 100,000 cfs; however, little damage occurred because the flood plains were largely covered by natural vegetation and were not developed. The most destructive flood occurred in 1916, when dams on the Sweetwater and Otay Rivers failed, with severe damage to transportation and communication systems, and 23 deaths. Discharge at Mission Valley was estimated to be 70,000 cfs; a comparable flood today would innundate commercial and residential areas, cause structural damage to buildings in the millions of dollars, result in major breakdowns of freeway systems, and probably be responsible for many deaths. Thus it is imperative that the effects of the sand blockage at the exit of the San Diego River Floodway be ascertained as expediently as possible.

31. As discussed by Mayo,[7] flood control studies of the San Diego River prior to 1964 did not adequately delineate the extent of floodplains. Local authorities, therefore, did not have available all the data necessary for guiding the urban growth within the river valley. Accordingly, an investigation was initiated by the State of California, Department of Water Resources, at the request of the County of San Diego, to delineate the areas subject to flooding along certain portions of the major coastal streams in the County. These studies[8] were directed toward producing reliable estimates of water-surface profiles for peak floods of 50- and 100-year recurrence intervals and to delineate these areas between Mission Gorge and El Capitan Reservoir; thus, the results are not directly transferable to the exit region of the San Diego River Floodway.

PART III: HISTORICAL DEVELOPMENT ASPECTS OF MISSION BAY

32. In historic times, Mission Bay was a natural estuary of over 4,000 acres with the major drainage feature into the estuary being the San Diego River. This river has alternately drained into either Mission Bay or San Diego Bay to the south. In 1876 the U. S. Army Corps of Engineers constructed an earthen levee which permanently diverted the river into Mission Bay, as it had been determined that if the San Diego River were allowed to continue to discharge into San Diego Bay, serious shoaling would result and would interfere with commercial shipping. At that time, Mission Bay was considered of little value relative to San Diego Bay; consequently the San Diego River was permitted to discharge into Mission Bay until around 1946.

33. The City of San Diego and the Corps of Engineers in 1941 initiated studies for considering improvements to the lower San Diego River for purposes of flood control. As these investigations progressed, it became evident that maximum benefits could be obtained by a combined flood control and navigation project at Mission Bay. The combined project was presented to, and adopted by, Congress in 1946, as House Document No. 760, 79th Congress, 2nd Session. The Federal Government would be responsible for the main channel and its side-slopes, the dredging of the west and east basins in the Bay, the dredging of the navigation entrance channel to the Bay, and the construction and maintenance of the three jetties defining the navigation and flood control channels. It had been realized that three jetties would be necessary in order to prevent the sediment-laden San Diego River from discharging into the Mission Bay proper. In 1942 the City of San Diego initiated dredging and filling operations in the Bay for public recreational developments.

34. Among other considerations, a well designed harbor system requires a balanced sedimentation system; i. e., it is desired that the forces due to waves, tides, and currents will be in equilibrium

such that neither scouring nor shoaling of movable material will occur as either phenomena can have detrimental effects on structures or navigation. Two potential sources of movable material exist in this semi-closed system: (1) sediment being transported downstream by the San Diego River and discharging into the surf zone adjacent to the Mission Bay entrance channel; and (2) littoral material from the longshore transport system being carried past and into the entrance channel by tide and wave forces. For these reasons, the concept known as the "non-scouring" tidal channel was developed for the entrance to Mission Bay. The inlet cross-sectional area was designed large enough so that tidal current velocities were reduced below their potential for moving bottom material. Regime studies of un-restricted channels in alluvial material indicate a unique relationship will develop between such variables as discharge, width, and depth; however, in this case of a definite restriction on the width by two parallel jetties, only the discharge and depth were considerations. Increased dredging costs due to channel over-design were a definite concern as was the potential for the introduction of more wave energy into the harbor complex, although it was believed reduced velocities in the entrance channel would tend to reduce hazards to navigation.

35. The Corps of Engineers initiated construction of the south and middle jetties for flood control purposes in 1948, and of the north jetty for navigation into the Bay in 1949. The south and middle jetties were completed in 1949, and the north jetty in 1950. At this time the middle jetty was not completely closed, and tidal flow into and out of the Bay was permitted to traverse by way of the flood control channel, with detailed discussion of the operation provided by Herron.[9]

36. A pilot channel was dredged between the north and middle jetties in 1950 to initiate the diversion of tidal flow from the flood control channel through the navigation channel. For a short period of time, the tidal flow of the Bay could be transmitted by two passages. Nature's response to this action was rapid, as the

cross-sectional area of the flood control channel began to decrease and was almost closed by 1951. When the final section of the middle jetty was constructed in 1951, the flood control channel completely closed by littoral material in transport in the surf zone blocking the exit to a height of +10 ft MLLW. The main entrance channel to the Bay remained open and increased in cross-sectional area slightly. At this time the Corps of Engineers portion of the project was shut down because of the Korean War, although the City of San Diego continued to dredge and fill in the Bay.

37. Dredging of the outer entrance channel to project dimensions was resumed by the Corps of Engineers in 1954. At this time it was discovered that sand from the littoral zone seaward of the north jetty was passing through the north jetty and into the entrance channel. It was apparent that this was taking place over the top of the core of the jetty, as the core was composed of small stone which was impenetrable by sand. In the design of the jetties, the core was established at MLLW. In 1955 a contract was awarded for placement of 3,000 tons of sealing stone on the seaward slope of the north jetty within the littoral zone, thus allowing the waves to drive the stone into the interstices. Ninety-five percent of the stone was graded from 1-1/2 in size to 6 in size, and this measure succeeded in retarding the movement of sand through the jetty. However, it was later discovered that infiltration had not been entirely stopped.

38. In 1957 the Corps of Engineers dredged the main entrance channel and Quivira Basin to a depth of -20 ft MLLW, and this relatively coarse sand was pumped to the eastern perimeter of the Bay to stabilize mud deposits. This dredging essentially permitted full and unimpeded tidal flow through the entrance channel and the west Bay. The effects of the Mission Bay jetties upon sand migrations are fully discussed by Frautschy and Inman.[10]

Channel Shoaling by Jetty Penetration

39. During the preparation in 1958 for the final revetment contract of the Mission Bay project, it was discovered that 70,000 cu yd of shoal material had intruded the entrance channel through the middle jetty along the littoral zone, and 16,000 cu yd had continued through the north jetty where the sealing stone had been placed previously. It was decided that the north and middle jetties must be sealed by such means as would produce a permanent and completely impenetrable barrier.

40. The jetties are 16 ft wide at the crest, which is 14 ft above MLLW, with side slopes 1 vertical on 1.5 horizontal extending to the ocean floor on both sides. The armor, composed of stone 1 to 15 tons in size, is 14 ft thick over the top of the core and about 10 ft thick over the sides of the core. The void ratio of the armor is generally about 35%, but the size of individual voids varies from a fraction of a cubic foot to several cubic feet. The voids are staggered, and only in exceptional cases does any system of voids provide a continuous corridor extending from any surface to the core. Thus, the prevailing structural characteristics of the jetty precluded all attempts to intrude, by action of gravity, any but the most fluid of substances. Also, head differentials and dynamic thrusting of impinging waves constantly caused water to surge back and forth throughout the armor section with considerable velocities. The known materials at that time could not be combined in a way to provide the fluidity required for intrusion through the existing voids and still resist the erosion effects of water in motion during solidification.

41. An experimental program was established in which many combinations of grouting materials were tested in order to determine which combination could be placed satisfactorily, and which would at the same time be able to solidify and seal the jetties. Hardness, more than strength, was desired because the grout barrier would be exposed to sea action in places and there would be some abrasive

effect upon surfaces exposed to sand particles in the attacking waves. A combination of beach sand, cement, and illite drilling clay was eventually determined to satisfy all the necessary requirements.

42. An experimental contract was awarded for the sealing of approximately 400 ft of the middle jetty with the grout previously developed. Drill holes were placed 8 ft on centers, a nozzle was inserted to the bottom of the hole, and withdrawn at such a rate as to form an imagined cone extending from MLLW to 10 ft above MLLW wherever possible. Before sealing started, there was a trench-like depression in the beach contiguous to the outside toe of the jetty, where the beach and jetty met. This depression was about 10 ft wide and about 2 ft deep near the MHWL, becoming progressively shallower and fading out at about -2 ft below MLLW. This was an ostensible indication that sand was passing through the jetty. As sealing progressed seaward, the depression filled and sand piled against the jetty to heights up to 1.5 ft above the average beach. Also, the beach as far as 150 ft away from the jetty began to gain in elevation. This appeared to be convincing evidence to Loudon[11] that the sand was being stopped by the grout sealing experiment.

43. In 1959 a contract was awarded for sealing an additional 880 ft of the middle jetty and 1,000 ft of the north jetty. Specifications were prepared on the basis of what had been learned and proved during the experimental construction. This effort is believed to have been successful in stopping the passage of sand into the navigation channel. Surveys indicate no further incursion of sand. Also visual inspection shows that a shoulder of sand along the channelward toe of the jetty, much in evidence before sealing, has disappeared since the supply of intruding sand has been cut off. Also, there is little doubt regarding the permanence of the work.

44. In the case of Mission Bay, any shoaling in the outer entrance channel results in nuisance and hazards to the navigation of small craft because shoals cause chaotic and breaking waves. Between 1955 and 1958, shoaling took place at an annual rate of 45,000 cu yd.

Data indicated that all of the sand found its way into the channel through the jetties at the littoral zone. To maintain project depth by dredging would have cost each year approximately 50% of the total cost for sealing the two jetties. Since this form of shoaling has been prevented, the rather high cost of sealing the jetties was not only justified, but was extremely cost effective.

Adjacent Shoreline Alterations

45. The Pacific Ocean shoreline within the near vicinity of Mission Bay consists of Pacific Beach to the north of the entrance channel, Ocean Beach to the immediate south of the entrance channel, and the Sunset Cliffs region immediately to the south of Ocean Beach. The Pacific Beach area appears to be fairly stable and is not experiencing significant alterations in planform.

46. The Ocean Beach segment of shoreline, a broad sandy beach approximately 0.6 mi long, extends from the entrance to Mission Bay down-coast to Niagara Street where steep rocky bluffs mark the beginning of the Point Loma peninsula. The area has been subjected to many alternate periods of erosion and accretion, with the worst erosion occurring in 1941. As a result of that damage, together with continued loss of beach areas in other shore segments of San Diego County, local interests requested the Corps of Engineers to make a beach erosion study of specific problem areas within San Diego County. One of the areas to be studied was the shoreline fronting the community of Ocean Beach.

47. The erosion control study of Ocean Beach was initiated in the fall of 1953, and the project was completed during the summer of 1955 by local interests. The effort consisted of the placement of about 275,000 cu yd of artificial beach fill dredged from the Mission Bay project at no cost to the Ocean Beach project, and the construction of a stone groin.

48. The Sunset Cliffs beach segment is the northern portion of the Point Loma peninsula and extends from Niagara Avenue southward to the southern boundary of the City of San Diego, about 3 miles upcoast of the tip of Point Loma. This entire stretch of shore is very rocky with occasional narrow beaches, small pocket beaches, rocky reefs extending from the shore, sheer cliffs rising 50 to 75 ft above narrow rocky shelving beaches, and numerous caves, arches, and irregular sections have been formed by wave action.

49. The erosion of the beach and cliffs in this region has been progressive for many years, but in the early 1960's began to progress much faster. The retreat of the bluffs damaged public streets and destroyed both public and private land and improvements. Individual efforts by property owners to combat the wave erosion were insufficient and for the most part failed in their purpose. In 1960, the State of California, Department of Water Resources, requested the Corps of Engineers to make a special study of the cliff erosion in the City of San Diego with the specific objectives of determining the extent and probable rate of erosion in the Sunset Cliffs-Point Loma area of the city, the cause of the erosion, and the most suitable remedial measures. Also it was requested that an analysis be made of potential shoreline improvements or plans of protection, the public interest therein, and the economic justification. The results of these extensive investigations were published by the Corps of Engineers[12] in early 1965 as a special study of Sunset Cliffs, with subsequent studies in 1977 and 1978.

50. For convenience in analyzing the shore problems involved, and the possible methods of correcting such problems, the Sunset Cliffs study area was divided into two segments. Segment A consisted of that reach of shoreline extending southward from Santa Cruz Avenue to Osprey Street, and Segment B extended southward from Osprey Street to Ladera Street.

51. It was determined that Segment A could be protected by some type of structure such as a stone or concrete seawall or revetment but the construction cost would be prohibitive. It was necessary to con-

sider some other type of protection, and the placement of a protective beach appeared to be the most satisfactory from the standpoint of construction simplicity. The placement of a protective fill along the toe of the bluff would fulfill two objectives of the local interests. They had expressed a desire for additional recreational beach in the heavily populated Ocean Beach-Point Loma section, and also a desire to create a rowing course in the San Diego River. Sufficient material could be obtained from the River and a rowing course could be created at the same time. It was estimated that approximately 720,000 cu yd of fill material would be necessary to complete the beach fill project. Another source of beach fill material for the proposed protective beach would be the entrance channel into Mission Bay. Some shoaling had occurred and it was estimated that approximately 150,000 cu yd of material were available above the project depth; however, with unrestricted over-dredging approximately 650,000 cu yd of material could be made available. Five protective groins necessary for retaining the beach fill would also be required, as there was limited knowledge of the direction and extent of littoral drift and movement of beach sand offshore and onshore. The dimensions of this proposed beach were approximately 4,000 ft in length and averaged about 200 ft wide.

52. The decision was made that the most feasible plan of shore protection for Segment B would be to provide stone revetments along the toe of the bluffs where required, rubble-mound walls or dikes across rocky points, and sealing or blocking off of existing caves. No additional work would be required in this section during project life after the initial construction. With some modifications, the recommended plans for the improvement of Segment B have been essentially installed.

53. The Segment A recommendations were never actually implemented, and in view of changed physical and environmental conditions which may have developed since the authorization of the project in 1966, a re-evaluation of the requirements of this segment was performed by U. S. Army Engineer District, Los Angeles, in 1977 and 1978.

54. The erosion of the shoreline in the Sunset Cliffs area has become increasingly more serious to the homeowners and has caused increased damage to both public and private improvements in recent years. Erosion is occurring from two separate processes: (1) wave induced erosion at the base of the cliffs; and (2) bluff top erosion from surface runoff and human activities. According to Klarin[13], the base of the cliffs is wave resistant, although vertical joints form lines of weakness which widen and extend upward by wave action, resulting in caves or open surge channels. In the vicinity of Del Mar Avenue, the toe of the bluff is actively eroding due to closely spaced jointing which is causing undermining of the upper slopes.

55. Measurement of the amount of cliff recession is composed of two parts, in the same manner as the erosion is occurring, and the rate of retreat is not the same in both cases because of the differences in the resistance to erosion of the formations. Comparison of 1952 and 1976 topographic surveys indicates an average cliff retreat in the vicinity of Del Mar Avenue at the present time of about 1.5 ft per year. Most of the remainder of the cliff line in Segment A has retreated little, if at all, since 1952.

56. Several alternative plans for erosion control in Segment A have been recently re-evaluated, all of which address shoreline erosion and not cliff stabilization in which the Federal Government cannot participate. These alternative plans include:

1. Status Quo
2. Sand Beach and Groins (the authorized plan)
3. Sand Beach, Groins, and Revetment
4. Revetment (1615 ft)
5. Revetment, Concrete Seawall, and Nature Walk
6. Revetment (1020 ft)
7. Offshore Submerged Breakwater and Sand Beach
8. Acquisition of Property
9. Offshore Kelp Bed

In January 1979, the City of San Diego again requested assistance from the Corps of Engineers for a solution of these problems, to wit:

> ".....In accordance with Section 55 of Public Law 93-251, the City of San Diego is requesting technical and engineering assistance for a shoreline protection project between Newport Avenue and Osprey Street at Sunset Cliffs..... The proposed project includes Segment A of the U. S. Army Corps of Engineers Sunset Cliffs project and is a continuation of the Segment B project constructed during 1971 through 1973. The San Diego City Council, in October 1978, after a number of public hearings, approved the concept of the rock revetment alternative for protection at the base of the cliffs between Santa Cruz Avenue and Osprey Street along with a program to stabilize the upper cliff formation between Newport Avenue and Osprey Street............."

The only alternative which can be justified economically at the present time is one which includes a beach with recreational benefits, according to the work of Klarin[13].

PART IV: HARBOR WAVE AND SURGE ACTIVITY

57. In general, a harbor may be defined as a relatively quiet body of water connected to the open ocean in such a manner by various physiographic or artificial features as to be shielded from the greater part of the wave energy prevailing in the open sea. This dampening effect is usually provided by various dissipation or reflection mechanisms. If wave energy enters a harbor at rates exceeding the rates of damping and outflow of energy, motion will necessarily amplify with time until modes of oscillation of the basin are excited and seiching or surging will result.

58. It appears that during major storms, lower Mission Bay is presently vulnerable to sea and swell conditions which are uncomfortably high, and also experiences high surge activity. The effect of this water surface movement is to cause boats and all floating objects to alternately rise and fall while swaying back and forth. The magnitude of the vertical rise is dependent on the wave height, while the horizontal forces and motions are dependent on water particle velocities and accelerations. In 1960, the Mission Bay Yacht Landing, located on the north side of Quivira Basin, reported 13 major-size yachts left this landing as a direct result of surge conditions. The reasons given all followed a standard pattern. Mooring lines were continually strained beyond their limits and broke, and boats could be expected to be loose on an average of once a week, resulting in collisions and insurance claims. Fenders and bumpers would not withstand the pounding received, and continual damage resulted to hull fittings due to the tremendous forces imposed. Prospective lessees of areas in Quivira Basin raised the question of the security of investments in boating facilities in a basin which appears to be excessively rough.

59. As a direct result of these damaging incidences, the Corps of Engineers contracted with Marine Advisers[14] for the establishment of a wave monitoring program in Mission Bay. Wave transducers were

located at six critical points in the Bay complex (one in the main entrance channel, one in the Bay-Harbor entrance channel, two in Quivira Basin, and two in Mariners Basin). These gages monitored all storms occurring in 1963, and analyses of these records indicated that, indeed, excessive swell heights exist in lower Mission Bay. Most prominent of these problems was that incident sea waves over 10 ft in height induce excessively high swell (greater than 2 ft) in the basins. Uncommonly high seiche was evident in the harbor.

60. It was determined that the beaches then surrounding Mariners Basin were effective in damping large amounts of wave energy, and it was therefore recommended that future developments do not eliminate those beaches in favor of vertical bulkheads or steep revetted slopes. During major storms, when sea waves approaching 20 ft arrive at the entrance channel, swell in the basins may reach 3 to 4 ft in height. Such events are probable occurrences of about 3.5 hr annually. No storm of maximum possible intensity had occurred at that time, so the harbor management had no opportunity to observe a maximum disturbance in the basins. The effect of these 3 to 4 ft high swells on the facilities already installed in Quivira Basin would not be catastrophic but would be sufficiently damaging to cause local interests to lose confidence to such degree that development of the lower bay could be curtailed or abandoned, in which case public benefits of considerable magnitude would be lost to the project.

61. There appeared to be two potential solutions to the problems existing at that time. One possibility was the construction of two jetties, one at Quivira Basin and one at Mariners Basin to physically block incoming wave energy. The second possibility was the construction of a jetty at Quivira Basin, and development of a new entrance to Mariners Basin with filling of the present entrance to be accomplished. The District Engineer of the Corps of Engineers[15] recommended that a physical model study be performed to ascertain which solution was optimal.

Physical Model Evaluation, 1969

62. The U. S. Army Engineer Waterways Experiment Station[16] performed a hydraulic model investigation of Mission Bay to determine the relative effects inside the harbor of waves of various magnitudes that approach the harbor site from the more significant storm directions, and to develop remedial plans as required to provide satisfactory wave-action conditions in Quivira and Mariners Basins.

63. No definite wave-height criteria were specified for use in determining plan adequacy in this Mission Bay study. However, it was believed sufficient to adopt standards that had been used in similar studies. A review of past model studies of small-boat harbors which are subjected to short-period wave action similar to that at Mission Bay Harbor shows that wave heights considered acceptable should not exceed 2 ft for more than a few hours per year, and preferably should not exceed 1.5 ft in the mooring area. According to these tests, wave heights in the existing harbor should be satisfactory. However, damage to boats moored in the harbor have been reported, which indicates that reducing wave heights alone may not be sufficient to eliminate entirely the damage to moored boats.

64. The results of a study by Raichlen[17] indicates that the fundamental frequency of oscillation of the boat and the system of boat mooring are important variables with respect to the surge of the moored boats. He found that the range of natural periods of oscillation of moored boats of similar size and type as those that moor in Mission Bay is usually within the range of storm-wave periods experienced in Mission Bay (2.3 to 22.0 sec). It was found to be theoretically possible to reduce the surge of small craft in Mission Bay Harbor satisfactorily by proper design of the mooring system and by requiring that certain mooring procedures be adhered to. It was recommended that, if the mooring system alterations were not satisfactory, then changes to the physical features of the harbor should be made.

65. Results of tests of different plans indicated that install-

ation of sheet pile groins in the curved portion of the south bank of the entrance channel would effect an overall reduction in wave heights in Mariners Basin and Quivira Basin of 42 and 24 percent, respectively. Modification of the south bank of the entrance channel into a series of right-angled steps resulted in height reductions of approximately 79% in Mariners Basin and 23% in Quivira Basin. The addition of the sheet pile groins to the stepped bankline did not result in any significant differences in test results.

66. The results of frequency-response tests showed definite tendencies toward resonance in both Quivira and Mariners Basins for wave periods near 80 and 140 sec. A small increase in the wave-amplitude ratio occurred in the vicinity of 45- to 50-sec periods; however, it was doubted that such a slight tendency toward harbor resonance could produce any significant response in moored boats.

67. In 1975 the City of San Diego passed a resolution urging the Corps of Engineers to conduct a study of alternatives, including an offshore detached breakwater for modification of the Mission Bay entrance. Because the earliest estimated date for construction of a permanent solution to the problem was the early 1980's, based on the then existing schedule for the project study, and since the surge problem appeared to be more severe in 1976 as reflected by property loss claims and hinderance of the ultimate design capacity of the harbor, the City of San Diego again in 1977 passed a resolution which

> ".....requests the United States Army Corps of Engineers, under the outstanding authority for the San Diego River-Mission Bay Project (House Document 760, 79th Congress, 2nd Session, July 30, 1946), to expedite the study of surge problems and hazardous boating conditions in Mission Bay through application of their total design capability and to consider within the present authorized study the surge problem inland of Mission Bay Bridge; and to investigate the existing conditions in Mission Bay and develop alternatives to implement an interim solution until the authorized study project can be completed and constructed...................."

Temporary Solution, Quivira Basin, 1978

68. In early 1978, the U. S. Army Engineer District, Los Angeles, developed a temporary solution to the existing problems associated with short period waves in Mission Bay to prevent further damage to boats and facilities and to provide an opportunity for the further development of Quivira Basin. It did not in any way preclude study of the final solution of the Quivira Basin problem, or other problems in Mission Bay.

69. During 1976 and 1977, it was observed that the stormy season generally lasts around four months, from December through March. The damaging conditions in Quivira Basin occur when high waves propagate down the entrance channel and the high waves are most pronounced during high tide. Most damage to the boats and the floating docks seems to occur with waves over 0.5 ft in height and between 8 and 16 sec period. Locally generated wind waves do not appear to cause damage, although the entire effect of seiching of long period waves may not be completely understood.

70. The Corps of Engineers has contracted with the California Department of Navigation and Ocean Development (DNOD) for the acquisition of prototype wave data in Mission Bay, by the installation of eleven transducers at selected locations throughout the problem area. During December 1977 visual observations were made by DNOD personnel charged with the responsibility of obtaining these data of the surge conditions that were then occurring in the Bay. In the basins, wave run-up on the riprap was observed to be occurring from 1 to 2 ft vertical excursion with 15 to 16 sec periods. Superposed on this wave was a combination cross basin and a long basin surge with a period on the order of 100 to 110 sec with a run-up on the riprap of about 3 ft. In the entrance channel at a point looking seaward midway between the north and middle jetties, the run-up on the riprap was from 4 to 5 ft with a period of about 16 sec. The harbor patrol was warning boaters about waves breaking completely across the channel at the entrance.

71. Regardless of the origin and the type of waves entering Quivira Basin and Mission Bay in general, a problem appears to exist with excessive swell entering the entrance channel, passing through the main channel, and continuing through the 400 ft opening into Quivira Basin. Thus, in order to reduce swell wave heights in the basin, the swell wave energy entering the basin must be decreased. In order to accomplish this feat, the following alternatives were considered:

1. Addition of a breakwater made of stone, concrete piles, steel sheet piles, or timber piles to reduce the width of the entrance channel to Quivira Basin.
2. Floating breakwater at the entrance to Quivira Basin.
3. Modification of the curved portion of the south bank of the entrance channel by:
    a. Adding sheet pile groins.
    b. Creating a series of right-angled steps.
    c. Construction of a center dividing wall approximately on the alignment of the north jetty.
4. Open the middle jetty to create an attenuation basin for wave action in the existing flood control channel.
5. Construction of overlapping sheet pile breakwaters in the entrance channel, normal to the existing jetties, approximately 500 ft apart.
6. Construction of detached offshore breakwater offshore of the existing jetties.
7. Construction of a submerged offshore breakwater offshore of the existing jetties.

72. The evaluation and comparison of all alternatives resulted in the recommendation by the U. S. Army Engineer District, Los Angeles, that a timber treated pile array by placed at the entrance to Quivira Basin. Among the considerations were the following:

1. The most promising place to stop most of the swell energy entering Quivira Basin, on a short-term basis, is at the entrance to the basin.
2. Among different types of breakwaters, treated timber piles are not only the most economical, but have proven to work on other jobs under similar conditions and can be easily removed.

The life span of treated timber piles is about 10 to 12 years, which is more than adequate for a temporary solution. Timber piles can also be constructed within the required time frame.

3. The length and orientation of the recommended breakwater were dictated by several factors. The most important factor was to be able to stop as much energy from entering Quivira Basin as possible while leaving a usable navigation opening.

The construction of this temporary solution was initiated during March, 1979. No maintenance is anticipated for the recommended timber pile breakwater throughout the project life. Upon implementation of a permanent solution, the temporary breakwater will be removed when it is no longer needed or when the timber pile has begun to deteriorate.

73. According to the work of Nizinski[18], continuing losses to all interested parties in Quivira Basin are estimated to exceed $1,000,000 per year due to the loss of rental fees, associated business, and delay in construction of Marina Village. An additional $500,000 has already been lost for replacement cost of damaged boats and structures due to excessive wave action.

PART V: WAVE CLIMATE ESTIMATE

74. Before permanent solutions to the problems existing at the Mission Bay complex can be developed, it is necessary to have a good understanding of the incipient wave conditions existing in the vicinity. The incoming wave trains not only directly affect the operation of the marinas, but also indirectly contribute to potentially significant areas of concern such as longshore transport of littoral material in the surf zone and erosion of the adjacent shorelines. Wave height, period, direction of travel, frequency of occurrence, and energy of wave groups are characteristics requiring consideration in all of the potentially troublesome areas. In turn, these characteristics are directly influenced by such physical factors as wave exposure, island sheltering, refraction and shoaling.

Wave Exposure

75. The degree to which a site is open to the directional spectrum of wave energy from distant and local storms is called wave exposure. The amount of wave exposure along the Mission Bay Littoral Compartment is dependent on the configuration of the mainland and the existence of the offshore islands. Complete wave exposure is reduced by the sheltering effects of the California coastline and the offshore islands of San Clemente, Santa Catalina, San Nicholas, Santa Cruz, Santa Rosa, and the Los Coronados Islands of Mexico. The Tanner Banks and the Cortes Banks, submerged shoal regions south of San Clemente Island, also reduce the exposure of wave energy spectrums having wave periods greater than about 11 seconds.

76. Different locations along the coastline are exposed to a different wave climate due to the fact that the physical orientation of the coastlines and the islands permit wave exposure windows to vary as one proceeds southward from Point La Jolla to Point Loma.

Hence, it is imperative that proper consideration be given to the particular point of interest regarding the degree of wave exposure. Due to the fact that the entire Mission Bay Littoral Compartment is relatively small (compared to the Oceanside California Littoral Cell), a determination of the average wave climate throughout the Compartment should suffice to evaluate longshore transport and incipient wave conditions at the Bay entrance.

Island Sheltering Effects

77. If the Mission Bay Littoral Compartment were not sheltered by the offshore islands, waves would arrive from a wide range of directions even if the direction of the wind in the generating area were relatively constant. According to Arthur[19], variability of wave direction makes a path of at least 45° on each side of the wind. A directional beam pattern of wave intensity of the form $(1 + \cos 2\theta)$ has been used to approximate this spreading function. In effect, the intensity is proportional to the square of the wave height, which is consistent with observational data. The result of sheltering, then, is to prevent certain parts of the wave rose from reaching the protected area.

78. In investigating island sheltering, the first consideration is to determine which directions of approach are open to waves of various periods and which are blocked. This cannot be accomplished by simply inspecting the sea level contours of the islands, for shoal water can act as a barrier just as effectively as an island shore. The blocking action depends on both water depth and wave period, with long-period waves requiring deeper water for passage than short-period waves; and as a result, any given opening between two islands will present a narrower portal to a long-period wave than it will to a short-period one. With the aid of precise bottom-contour charts, all such avenues of approach were listed for the Mission Bay Littoral Compart-

ment, and the required integrations were performed by digital computer utilizing a program developed by U. S. Army Engineer District, Los Angeles. The precise point selected to ascertain the deep water wave climate was located directly off the main entrance channel to the Bay in water of 300 ft depth.

79. The island sheltering theory yields not only height-reduction ratios but indicates modification in direction as well. Periods are assumed to remain unchanged. The direction modifications are necessary because, in some cases, sheltering will block out part or all of the primary central portion of the direction sector of a train of approaching waves. When this happens, the wave energy reaching the hindcast point will obviously come from around the two ends of the barrier, and the resulting modified wave train will come from a direction within the original sector but modified toward that end of the barrier around which the larger part of the remaining wave energy came. The island sheltering coefficients, or the percent remaining of the original deep-water wave heights, and the direction-of-approach alterations were applied to the deep water wave climate being utilized in the analysis. The resulting sheltered deep water wave climate was then refracted shoreward to the site of interest. The sheltered deep water depth in all cases was 300 ft where the refraction analysis was initiated.

Refraction and Shoaling Effects

80. The phase speed of a surface gravity wave depends on the depth of water in which the wave propagates. As the wave celerity decreases with depth, the wave length must also decrease for the period to remain constant. Variation in phase velocity occurs along the crest of a wave moving at an angle to underwater contours because that part of the wave in deeper water is moving faster than that part in shallow water. This variation causes the wave crest to bend toward

alignment with the contours. This bending effect, called refraction, depends on the relation of water depth to wave length. It is analogous to refraction of other types of waves, such as light or sound.

81. As waves propagate from deep water into shallower water, changes other than refraction take place. The assumption generally made is that there is no loss of wave energy and negligible reflection. The power being transmitted by the wave train in water of any depth is equal to the power being transmitted by the wave system in deep water. The wave period remains constant in water of any depth, whereas the wave length, velocity, and height vary.

82. The transformation of irregular ocean waves is a complex process which is not fully understood. The usual method of treating the problem (which is both practical and relatively successful) is to represent the actual system by a series of sinusoidal waves of different heights, periods, and phases. Such a system now has a two-dimensional energy spectrum. The wave statistics being analyzed in the present study are treated in this manner.

83. Refraction and shoaling effects are important for several reasons. These phenomena determine the wave height in any particular water depth for a given set of incident deep-water wave conditions; i. e., wave height, period, and direction of propagation in deep water. Refraction and shoaling, therefore, have a significant influence on the distribution of wave energy along the coast. The change in wave direction of different parts of the wave results in convergence or divergence of wave energy, and materially affects the forces exerted by waves on structures and the capacity of waves to transport sand either longshore or onshore/offshore.

Data Sources

84. The U. S. Navy Fleet Numerical Weather Central (FNWC) has produced synoptic wave analyses for the northern hemisphere since 1946.

These data are archived on magnetic tape, and have been recently utilized by Meteorology International, Inc. (MII) under contract with DNOD to provide deep water wave statistics for coastal engineering applications similar to those previously prepared by National Marine Consultants[20] (NMC, 1960) and Marine Advisers[21] (MA, 1961), which have been the basis of design for coastal projects in California. These statistics by Meteorology International, Inc.[22] (MII, 1977) not only increase the data base (from 3 to 29 years), but also refine the wave direction increments from 22 1/2^{o} to 10^{o} and provide additional information on persistence of waves of various heights. These deep water open-ocean wave statistics compiled from a 29-year data base (1946-1974) are available from DNOD for six hypothetical stations along the California coast.

85. The singular wave model used by FNWC is based upon converting barometric observations from ship and shore stations into a pressure field. A wind field is mathematically derived from this pressure field and imposed on a grid covering the northern hemisphere. At each grid point wave heights, periods, and directions are mathematically generated for each 24-hour period. If the wind wave is 5 ft or more in height, a swell train is initiated along a great circle track in the same direction as the wind wave and carried from grid point to grid point until the swell wave decays to less than 3 ft or reaches land. At each grid point, both the wind wave (sea) and a swell wave are recorded.

86. The FNWC grid system does not follow the California coastline, and it was deemed desirable to have deep water statistics available near the coast at convenient intervals for a number of coastal engineering applications. Six locations were chosen, Figure 5. MII Stations 5 and 6 along the Southern California coast are sufficiently offshore in deep water so that island effects not considered by the numerical model are avoided. Consideration was given to decreasing the distance between stations; however, it was determined that for most applications, an interpolation between stations is sufficient,

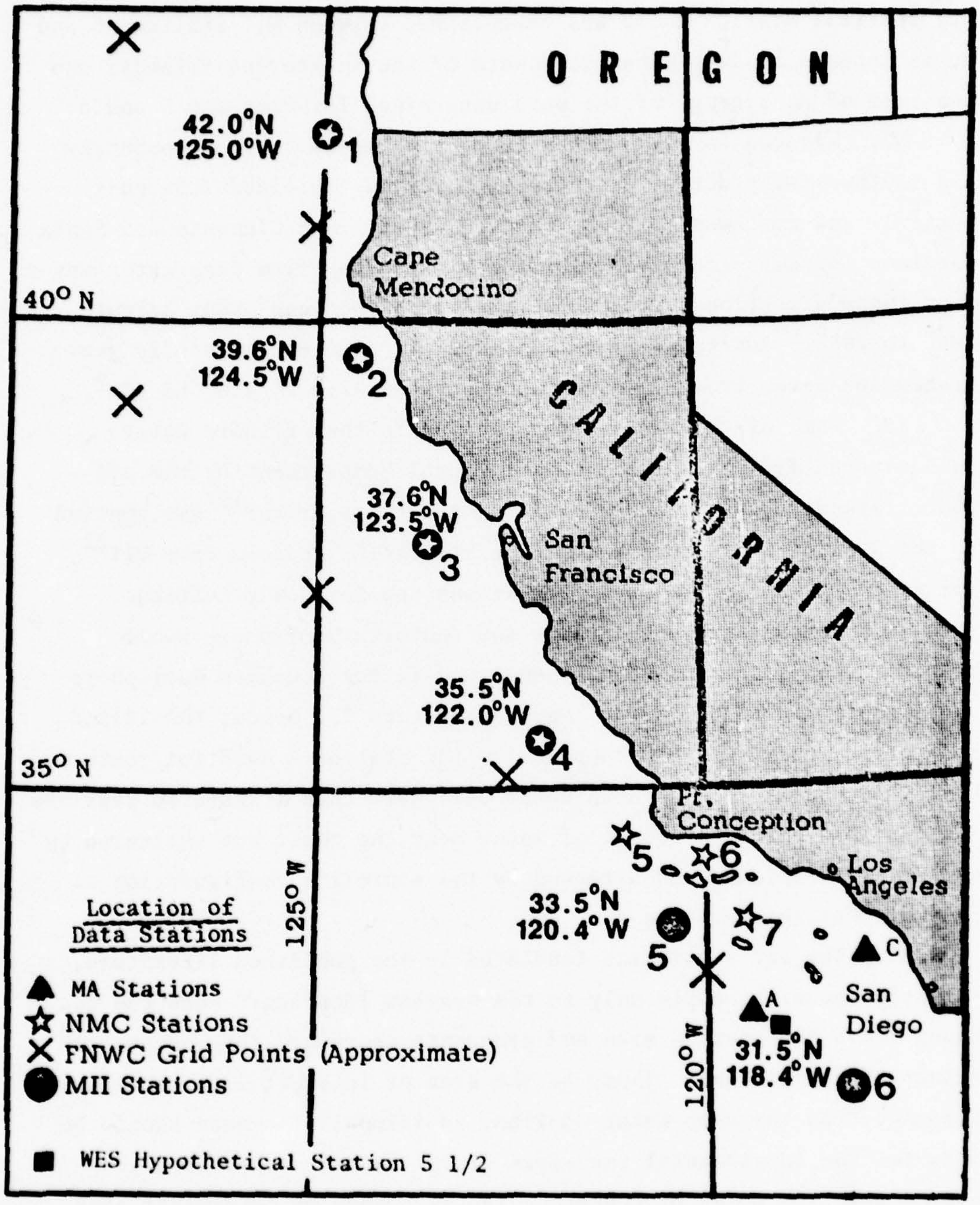

Figure 5. Location of deep water wave statistical stations off the coast of California by National Marine Consultants, Marine Advisers, and Meteorology International, Inc. (after Meteorology International, Inc.)

as the variation between stations was quite smooth. Accordingly, a hypothetical Station 5 1/2 was established between MII Stations 5 and 6, is located in deep water oceanward of the sheltering islands, and consists of an average of the data determined for Stations 5 and 6.

87. Mission Bay is exposed to deep water waves from southerly and southwesterly directions, but is partially shielded from most westerly and northwesterly approaching waves. San Clemente and Santa Catalina Islands effectively shelter Mission Bay from deep water waves from these directions, except for the sector between about azimuth 285^{o} to 295^{o}. Additionally, Mission Bay is exposed to locally generated sea waves from all directions between azimuth 180^{o} to 330^{o}.

88. Some of the wave energy present in the offshore waters is sheltered from the Mission Bay Littoral Compartment by the offshore islands. The island sheltering theory of Arthur[19] was applied to the Station 5 1/2 deep water wave statistics deduced from MII[22], for northern hemisphere swell conditions and for sea conditions. Because these data do not include any southern hemisphere swell considerations, the most comprehensive data for southern hemisphere swell continued to be that of Marine Advisers[21]. Hence, the island sheltering theory was also applied to the Station A data for southern hemisphere swell. These deep water data were then transfered past the islands to a point in 300 ft of water near the coast but sheltered by the offshore islands and affected by the shoreline configuration of Southern California.

89. The sea statistics tabulated in the published literature, strictly speaking, apply only to the station location. When the sea waves leave the station area and propagate shoreward they become, in effect, "decayed sea." Thus, if the area of interest is a significant distance from the deep water station, additional allowance should be made for the supplemental sea waves (local sea) that has been generated near the point of concern. The frequency of occurrence statistics used in this study include the contributions from northern swell, southern swell, decayed sea, and local sea. The local sea

characteristics were developed from the wind fields accessed from the Synoptic Shipboard Meteorological Observations (SSMO) data tapes.

90. The NOAA/EDS SSMO data tape family was derived from over 31 million surface marine observations obtained from ship logs, ship weather reporting forms, published ship observations, automatic observing buoys, teletype reports, and from cards purchased from several foreign meteorological services. The quality of instruments used to make the measurements, as well as the qualifications of the observers, varied considerably; however, a diligent effort has been made to bring to the researcher of oceanic weather patterns and sea conditions, a common observational format, designed for use with modern electronic data processing equipment.

91. In recent months questions have arisen regarding the applicability of using a singular wave model for the determination of wave statistics. Most knowledgeable researchers agree that the spectral approach is significantly better and, indeed, the U. S. Army Engineer Waterways Experiment Station is presently engaged in a 5-year project to provide, thru hindcasting, a directional spectral wave climatology for all continental United States coastlines and Hawaii. This wave climatology will ultimately be available in the form of a computer-based wave information system with the capability to perform nearshore wave transformations such as those necessary for this study. However, the data results for the coast of California for this new study will not be available until the latter part of 1980; hence, it is not possible to delay an investigation of the Mission Bay problems until these comprehensive data become available. Consequently, the only viable alternative at the present time is to proceed with analyses based upon the best information available, which is believed to be MII statistics for northern hemisphere swell and decayed sea waves, MA statistics for southern hemisphere swell, and the SSMO data tapes from which the local sea conditions can be developed. Results and conclusions will be revised and up-dated as more precise wave data become available.

92. Longshore transport computations were performed for the Mission Bay Littoral Compartment by applying refraction analyses to the latest hydrographic survey data which was overlain by a 400 ft square depth grid. This provided adequate detail and permitted the computations to proceed to the breaker zone for all wave conditions. The refraction analyses thus provided a series of calibration curves for selected wave heights and periods for each direction-of-approach band. From these calibration curves of the effect of deep water wave height, period, and direction of approach on breaker height (Appendix A) and of these same effects on breaker angle (Appendix B), the appropriate value for each element appearing in the wave statistics matrix could be determined. Ultimately, the amount of potential longshore transport attributed to that element was evaluated.

PART VI: RESULTS AND CONCLUSIONS

93. The occurrence of deposition or erosion along any beach is a result of a number of inter-related factors, including the amount of available beach material, the location of its source, the configuration of the coastline and of the adjoining ocean floor, and the effects of wave, tide, and current action. The existence of a sand beach is the result of a delicate dynamic balance between a number of these factors, and changes in any of the influential forces tend to perturb the dynamic equilibrium.

94. Prior to construction of the jetties at Mission Bay, sand moved by longshore currents in both directions along the coast. The littoral material crossed the shallow bar at the entrance to Mission Bay and moved without significant dissipation in either direction. Northward flowing currents would remove material from Ocean Beach and transport it northerly toward Pacific Beach, but alternately southward currents would tend to return most of the material. This, coupled with occassional cliff erosion at Sunset Cliffs, tended to maintain a fairly substantial beach at Ocean Beach. The jetty construction had two important effects on the flow of littoral material: (a) they impede the natural flow of sand along the region; and (b) they form wave and current shadows which result in quiet water and the deposition of sand near the jetties.

95. Long-term (permanent) solutions to the four principal problems which exist at Mission Bay must be developed with an understanding of their effect upon the littoral regime of the area, and vice versa, of the consequences of sand transport (scour and deposition) upon the functional design of the structural alternatives. It was requested that the U. S. Army Engineer Waterways Experiment Station apply the latest wave statistical data for this region to ascertain an estimation of potential longshore transport to be used in the development of possible alternative solutions.

Longshore Transport Analysis

96. According to the Shore Protection Manual[23], it is accepted practice to use calculated wave conditions to compute a longshore component of "wave energy flux" which is related through an empirical relationship to longshore transport rates. This conceptual model is based on the assumption that longshore transport rates, Q, depend on the longshore component of energy flux in the surf zone. The longshore energy flux in the surf zone is approximated by assuming conservation of energy flux in shoaling waters, using small-amplitude theory, and then evaluating the energy flux relationship at the breaker position. Ultimately, based on these assumptions, it can be shown that:

$$Q = (7.5 \times 10^3)\ P_{1s} \quad (1)$$

where

$$P_{1s} = 32.1\ H_b^{5/2} \sin 2\ a_b \quad (2)$$

In Equations 1 and 2, Q is the longshore transport rate in cu yd per year, P_{1s} is the surf-zone approximation of the longshore component of wave energy flux in the direction of wave advance per unit length of beach, H_b is the breaker height in the surf zone for a particular wave period and deep water wave height, and a_b is the breaking angle in the surf zone which the particular wave associated with H_b makes with the shoreline.

97. The frequencies of annual occurrences of open-ocean deep water wave characteristics are presented in Appendix C. When these waves have propagated shoreward of the islands and have been accordingly altered in both direction and amplitude, although still in deep water, the accumulation of these sheltered frequencies (Appendix D) will still be influenced by nearshore topographic effects. Ultimately breaking will occur, and the magnitude of the breaker height and the

angle of breaking with the beach are important parameters in evaluating potential longshore transport of littoral material. The individual matrix element computations are shown in Appendix E.

98. A summary of the potential longshore transport computations is presented in Table 2 where it is noted that on a net movement basis, the Mission Bay Littoral Compartment is essentially in dynamic equilibrium. The approximately 20,000 cu yd estimate of net northerly transport of material is probably not within our ability to discriminate, based upon the accuracy of the methods and information used to develop the tables of wave statistics. On the other hand, the computations indicate that the average wave climate has the potential for moving large quantities of material on a gross basis, in the presence of an unlimited supply of material. Any calculation of a longshore transport rate is an estimate of potential transport. If sand on the beach is limited in quantity, then calculated rates will indicate more sand in transport than there is sand available. Indeed, the sand of the Mission Bay Littoral Compartment is not unlimited in quantity, a fact reflected by both the limited extent of the region, and by the erosional characteristics of the Sunset Cliffs area.

99. Thus the computations of the potential longshore transport rates for the Mission Bay region should be considered with an understanding that, on a net basis, the Compartment is probably in a state of near dynamic equilibrium. However, since there is insufficient littoral material to maintain the beach in the Ocean Beach-Sunset Cliffs area, the gross values of the potential longshore computations probably do not reflect the proper magnitude of sand movement, and would only do so in the present of an unlimited supply of material. Prior to the diversion of the San Diego River from Mission Bay in 1948-1950, much of the beach building material carried by this river was deposited in the Bay, and was than carried to the beaches during times of large flood runoff. This material carried to the ocean was sufficient in quantity to maintain a beach at the toe of the bluffs along most of the

Sunset Cliffs area. However, in recent years, this protective beach has gradually disappeared because of the below-normal rainfall in conjunction with the flood control structures on the San Diego River; hence, there has resulted a greatly reduced volume of runoff and the quantity of material supplied to the region has been insufficient to maintain the beach. Thus, the potential gross monthly longshore transport shown in Figure 6, and the potential monthly longshore transport of Figure 7, represent that volume of material which would have been expected to be moved by the wave regime prior to about 1950.

100. Alternatively, the potential net monthly longshore transport of Figure 8 probably is still within the range of current values inasmuch as this represents the difference between two transport rates which have probably changed proportionally.

101. Nordstrom and Inman[24] have documented tremendous onshore/offshore sand movement with season at Torrey Pines State Park, just north of La Jolla. These seasonal changes were definitely related to the changes in wave regime. During the summer months the beach profile progressively changes with the seaward progradation of the berm crest by sand accretion. This change was caused by onshore transport of sand from immediately offshore depths of less than -20 ft MLLW. The transition from the summer to the winter beach profile was abrupt with the coincident occurrence of high waves and tides. Periods of high waves during high tides resulted in wave swash overtopping the berm crest and quickly eroding the beach. The rapid shoreward retreat of the berm crest caused by the offshore transport of sand was accomplished by a corresponding deposition of sand offshore at depths less than -30 ft MLLW. These same mechanisms are probably causing similar phenomena to occur at the Mission Bay region.

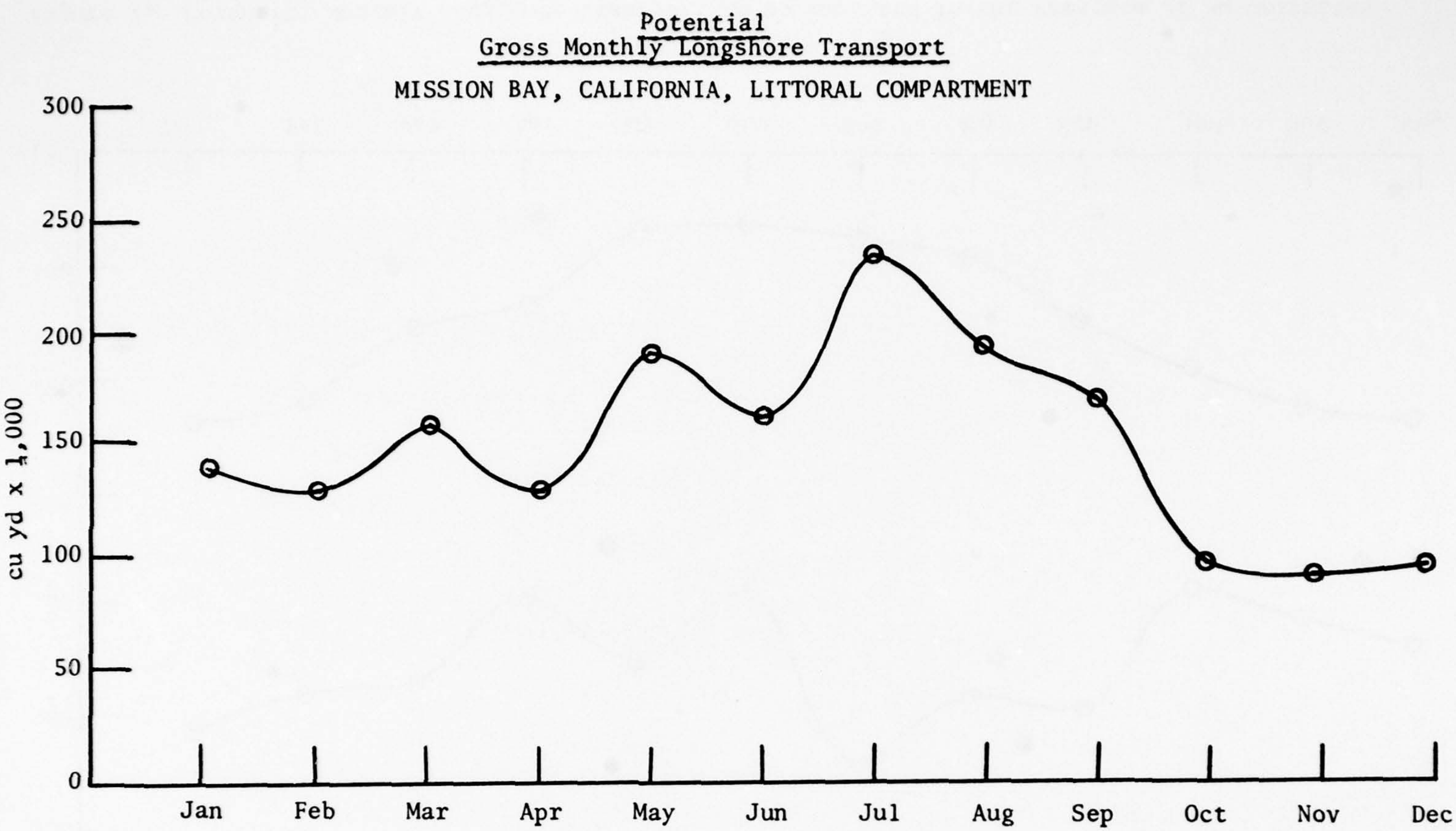

Figure 6. Potential Gross Monthly Longshore Transport to be Expected in the Presence of an Unlimited Supply of Littoral Material at Mission Bay, Probably Prior to 1950.

Potential
Monthly Longshore Transport
MISSION BAY, CALIFORNIA, LITTORAL COMPARTMENT

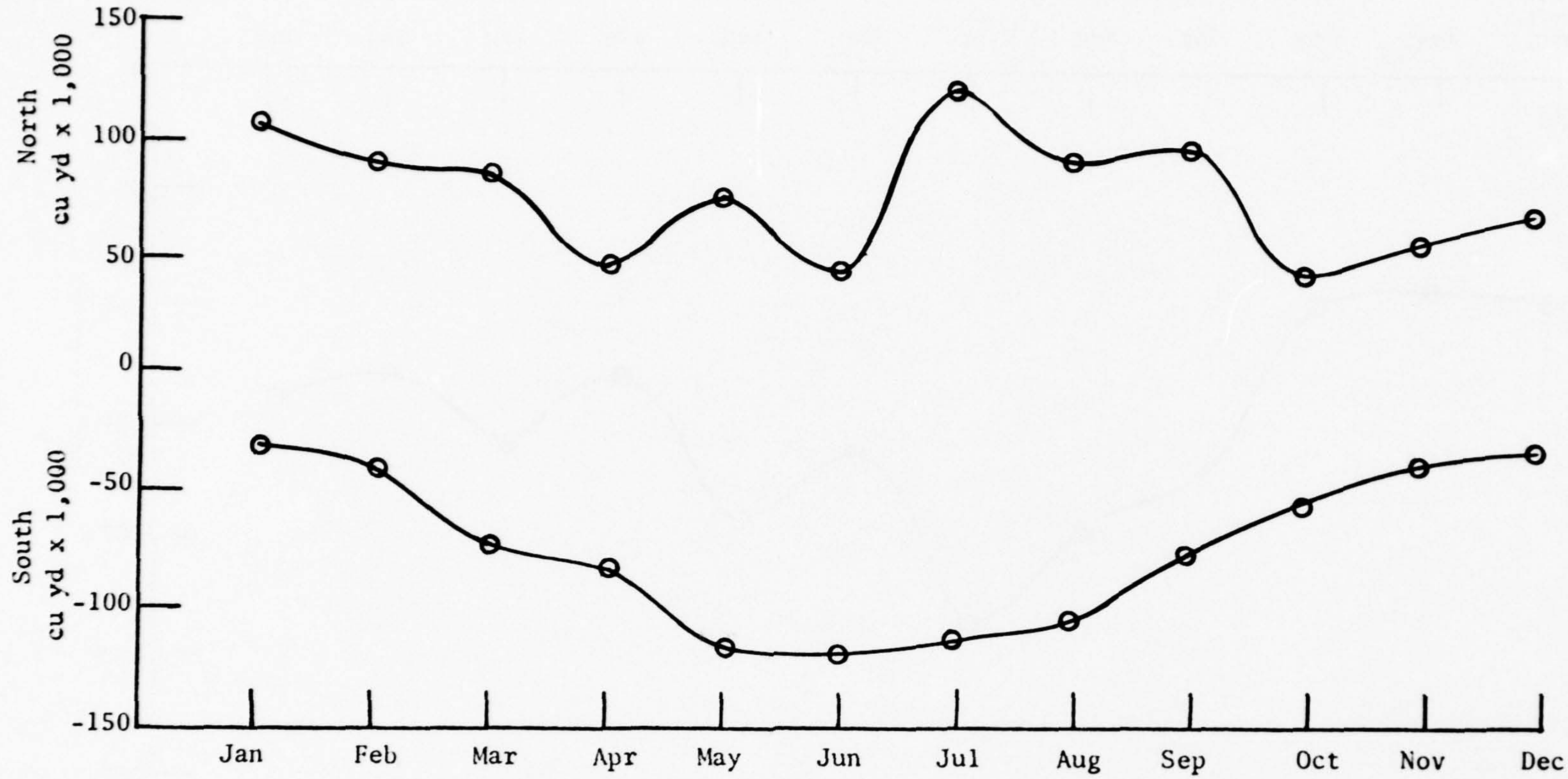

Figure 7. Potential Monthly Longshore Transport to be Expected in the Presence of an Unlimited Supply of Littoral Material at Mission Bay, Probably Prior to 1950.

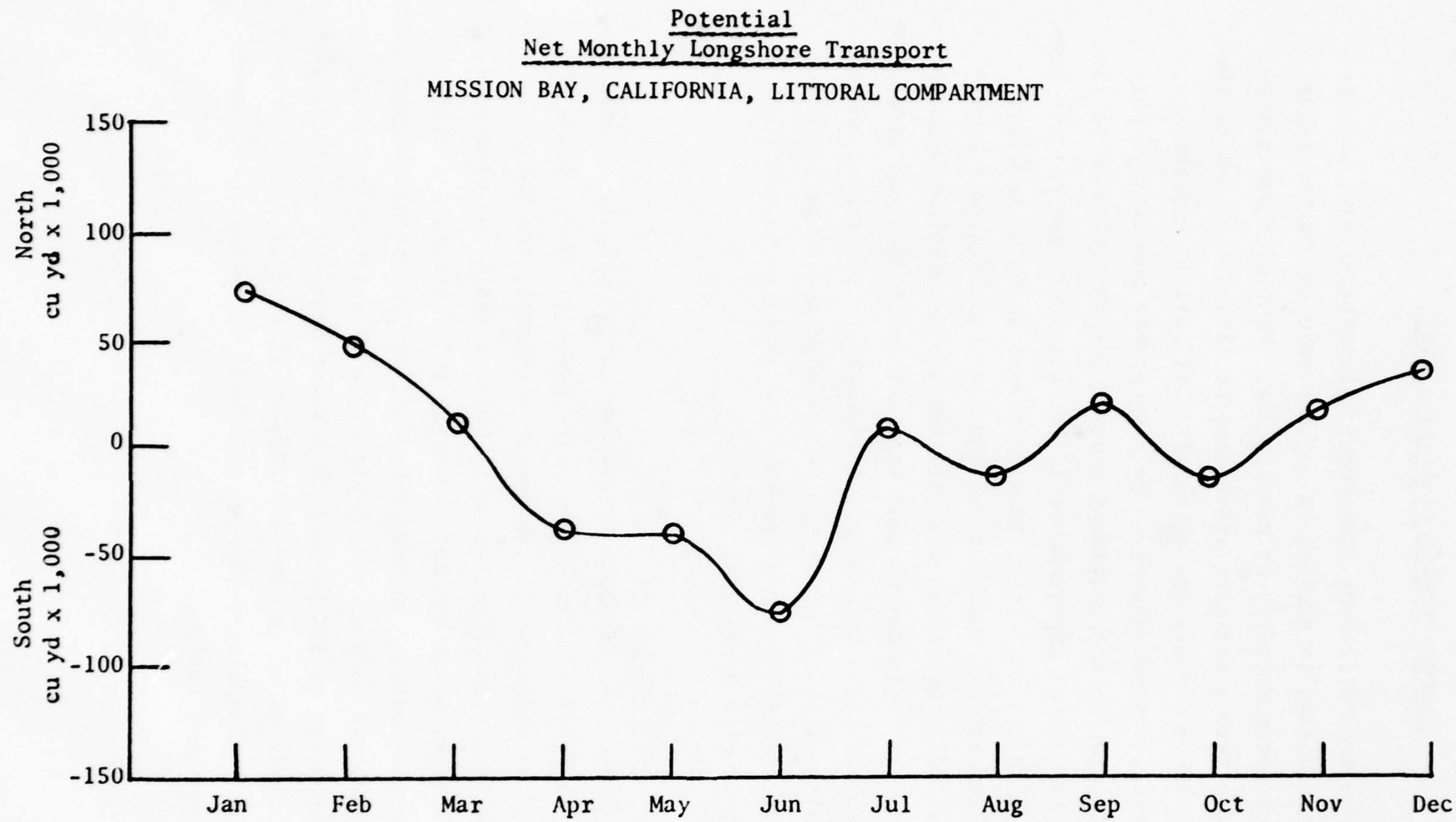

Figure 8. Potential Net Monthly Longshore Transport, Mission Bay.

Harbor Structural Alternatives

102. Several different structural alternatives have been proposed for evaluation to provide an optimum solution to the major problems presently existing at Mission Bay. Most of these alternatives would have a definite effect on the littoral regime of the region, and these effects are extremely difficult to hypothesize from analytical considerations. The appropriate theoretical work necessary to provide computational schemes for the solution of the effects of structural improvements in the littoral zone has not been developed at this time. It is known a priori that the combined effects of refraction, diffraction, shoaling, and sediment availability must be incorporated with erosion and deposition characteristics in a wave field environment in order to predict the effect of a particular structure on a particular prototype location. Due to the complexity of the problem, the only viable method of analyzing the efficacy of alternative proposed structural improvements for Mission Bay is with a physical model.

Detached Offshore Breakwater

103. A detached offshore breakwater would probably be effective in alleviating at least two of the major problems, those being the dangerous wave conditions at the entrance channel, and the short period wave conditions experienced in Quivira Basin and elsewhere in the Bay. This solution may not, however, solve the long period problems in the basins. Whether submerged or protruding through the water surface, the cost of such a structure is relatively high (estimated on the order of $10,000,000 in a water depth of 28 ft, $12,000,000 in a water depth of 30 ft, and $17,000,000 in a water depth of 35 ft.); thus, breakwater stability studies also will be necessary to assure optimum structural design.

North Jetty Extension

104. By extending the north jetty seaward and then curving the jetty southward beyond the entrance to the Bay, some benefits of a detached breakwater would be achieved at less cost than a completely new breakwater. Most of the northern hemisphere swell and sea conditions would be eliminated from penetrating the harbor. Southern hemisphere swell will affect this operation to an unknown extent as sediment swept into the entrance channel will not be transported northward to nourish Pacific Beach, and consequently the potential for beach erosion will exist in this region.

Middle Jetty Extension

105. In a manner analogous to the above discussion, a proposal exists for the extension of the middle jetty seaward past the end of the north jetty, and then curving the middle jetty northward beyond the entrance channel. This configuration would eliminate southern hemisphere swell from penetrating the channel, but northern hemisphere swell and sea which occur a relatively large percent of time would be permitted to enter the channel. Also, the southern transport of littoral material would be altered and erosion of Ocean Beach might result.

Entrance Channel Constrictions

106. In order to eliminate much wave energy penetration through the entrance channel to the Bay, consideration is being given to the construction of stone groins perpendicular to the parallel jetties for the purpose of constricting the area available for wave penetration. While this procedure would probably be effective from a wave energy standpoint, this would be a serious obstruction to navigation, would probably not solve the long period problem, and would probably adversely affect tidal flushing of Mission Bay and alter current velocities in the channel. Thus, this proposal may not be a viable long term solution.

Floodway Alterations

107. While any of the above considerations for structural improvements near the entrance channel may result in shortening of the north and/or middle jetties, it appears one potential solution to the elimination of the sand plug formation at the exit of the San Diego River Floodway would be an extension of the south jetty through the surf zone to a depth sufficient to preclude complete blockage. Partial filling of the exit will result as littoral material moves northward and southward past the region, but flooding would probably remove any undesirable constriction, whereas in the existing situation, this probably would not be true. Any material removed from the existing blockage could be utilized as downcoast beach nourishment which could be expected to remain in place with construction of the appropriately designed structural features.

Physical Model Necessity

108. The position of the U. S. Army Engineer Waterways Experiment Station (WES) regarding technical recommendations concerning a physical model of the Mission Bay region was transmitted from the WES Technical Director to the District Engineer, U. S. Army Engineer District, Los Angeles, by letters of 26 October 1977 and 11 January 1979, and is summarized in the following paragraphs.

109. A physical hydraulic model will be the best means of investigating hazardous entrance channel conditions, short period wave action in the boat basins, and effects of an offshore structure on surfing. In addition, this model could be used to study certain aspects of flooding of the San Diego River, effects of an offshore structure on tidal flows, and entrance channel shoaling conditions. Reliable model data can be obtained to evaluate and solve the above problems without reproducing the entire Mission Bay complex. Conse-

quently, the model would have artificial boundaries with wave absorbers at the Midway Drive Bridge and at Bahia Point. This model could be used to study long period harbor oscillations, within certain constraints.

110. It is the WES understanding that long period harbor oscillations may be a primary cause of the damage to boats and facilities in Mission Bay, particularly in Quivira Basin, and that a wave and surge measurement program is being initiated to study this problem. Results from this study should provide beneficial guidance to the potential long period harbor oscillation tests in the physical model by producing a good estimate of the periods and modes of oscillation for Quivira Basin.

111. Since a detached breakwater seaward of the existing jetties is one of the alternatives being considered to alleviate undesirable wave conditions in the Mission Bay entrance channel and boat basins, some concern has arisen regarding effects of this breakwater on tidal circulation in Mission Bay. This problem could be studied using a finite difference numerical tidal circulation model similar to the one used in the Los Angeles and Long Beach Harbors' study. Since it is not anticipated that the proposed modifications will influence the tidal prism in Mission Bay, a comparative study of existing conditions versus the proposed improvement plan should be sufficient to evaluate this problem. This approach would use an ocean tide typical of the area as imput at the seaward boundaries of the numerical model.

112. Should results of hydraulic model and/or numerical models indicate that construction of an offshore breakwater is desirable and feasible, it may be advantageous to conduct breakwater stability studies to assure the optimum structural design. Such studies can often result in considerable construction (and maintenance) savings.

113. It is WES' recommendation that a hydraulic model study to investigate sea and swell problems, San Diego River flooding, entrance channel shoaling, and long period oscillations be conducted at the very minimum. If an evaluation of the effect of the proposed plans

on tidal circulation is necessary, then a comparative numerical tidal circulation study is recommended. A numerical harbor oscillation study of the same area as that included in a physical hydraulic model is not deemed to be cost effective relative to the cost and increased reliability of a physical model, and is therefore not recommended if a hydraulic model is constructed.

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Table 1

Flood Discharges on the San Diego River

Santee, California

Floods in Order of Decreasing Magnitude	Peak Discharge at Santee, Calif.* Under Conditions at Time of Flood, cfs.	With El Capitan and San Vicente Reservoirs in Operation, cfs.	No. of Times Discharge would be Equaled or Exceeded in 100 years.
Jan 1862	94,000	80,000	0.7
Jan 1916	70,200	58,000	1.7
Feb 1884	60,000	49,800	2.7
Feb 1927	45,400	35,700	3.6
Jan 1895	45,000	35,300	4.6
Dec 1889	34,000	25,600	5.6
Feb 1891	33,500	25,100	6.6
Feb 1874	33,000	24,700	7.6
Mar 1906	32,000	23,800	8.6
Mar 1867	30,000	21,800	9.6
Dec 1921	16,700	9,500	10.5
Feb 1937	14,200	7,100	11.5
Mar 1918	12,000	5,300	12.5
Jan 1909	10,000	4,600	13.5
Jan 1952	9,390	4,450	14.5
Apr 1941	9,250	4,400	15.5
Mar 1938	7,350	3,800	16.5
Feb 1932	7,400	3,200	17.5
Feb 1969	1,600	1,600	19.0

*Conditions at time of flood are recorded discharges. With El Capitan and San Vicente Reservoirs in operation are estimated discharges.

(Source: U. S. Army Corps of Engineers,[5] and California Department of Water Resources Bulletin 69-69.[6])

Table 2

Summary of
Potential Longshore Transport Computations

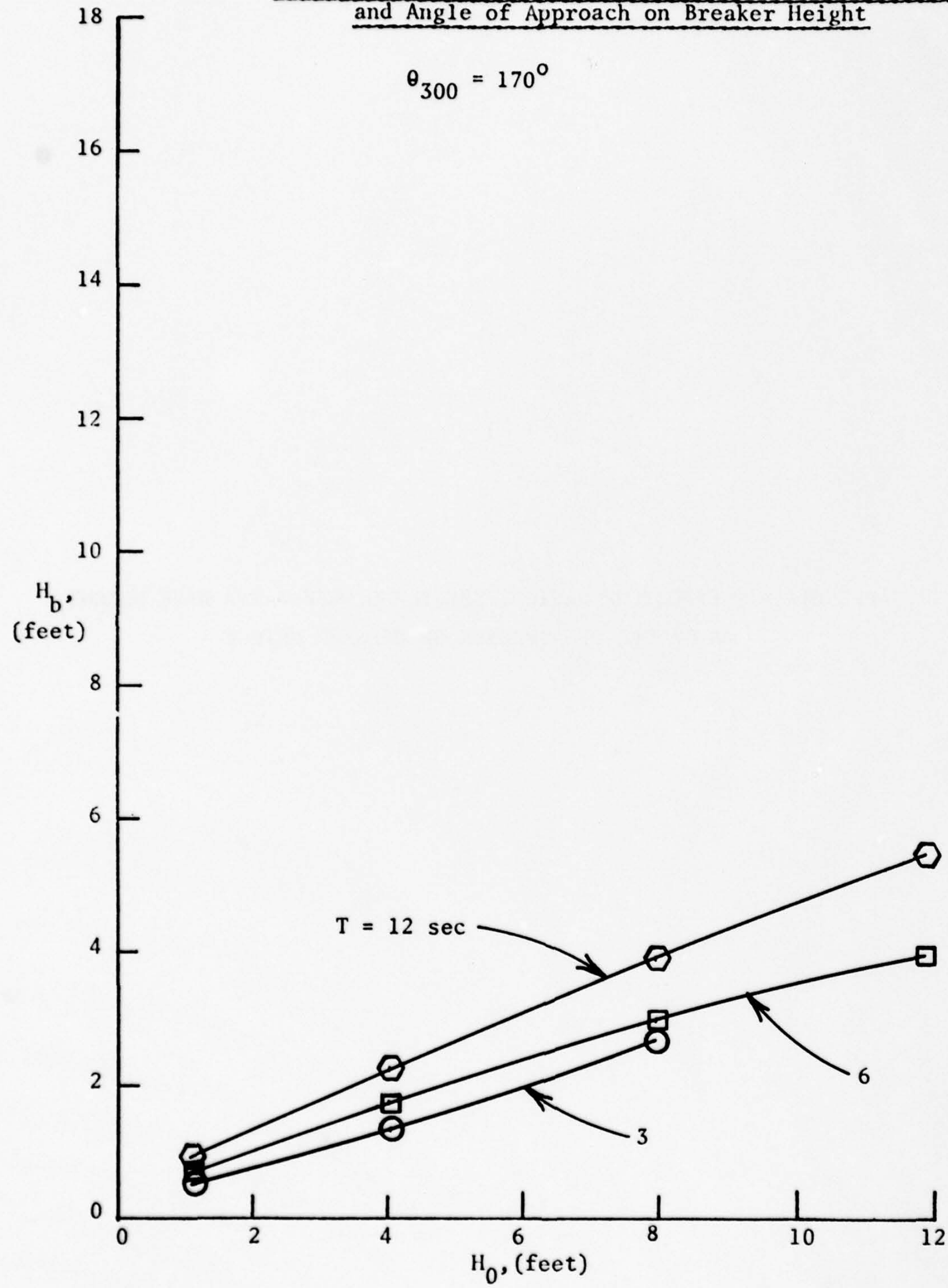
(all values in cu yds)

	Sea		Northern Swell		Southern Swell		Sum		Net		
	+	-	+	-	+	-	+	-	+	-	
Month	North	South	North	South	North	South	North	South	North	South	Gross
Jan	92,500	25,383	13,747	9,073	0	0	106,247	34,456	71,791		140,703
Feb	78,053	31,728	10,433	9,911	0	0	88,486	41,639	46,847		130,125
Mar	57,085	60,032	26,567	15,112	0	0	83,652	75,144	8,508		158,796
Apr	37,823	69,198	7,251	16,028	0	0	45,074	85,226		40,152	130,300
May	4,816	88,940	389	27,728	70,195	0	75,400	116,668		41,268	192,068
Jun	4,013	89,646	252	29,552	39,101	0	43,366	119,198		75,832	162,564
Jul	1,605	87,530	0	26,897	119,563	0	121,168	114,427	6,741		235,595
Aug	0	86,120	259	19,281	90,828	0	91,087	105,401		14,314	196,488
Sep	4,816	67,083	913	8,842	90,056	0	95,785	75,925	19,860		171,710
Oct	8,829	49,363	519	7,127	32,851	0	42,199	56,490		14,291	98,689
Nov	52,270	28,908	3,366	9,416	0	0	55,636	38,324	17,312		93,960
Dec	59,494	21,152	7,201	10,496	0	0	66,695	31,648	35,047		98,343
Annual	401,304	705,083	70,897	189,463	442,594	0	914,795	894,546	206,106	185,857	1,809,341
Net		303,779		118,566	442,594		20,249		20,249		

APPENDIX A: EFFECT OF PERIOD, SHELTERED DEEP WATER WAVE HEIGHT, AND ANGLE OF APPROACH ON BREAKER HEIGHT

MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Height



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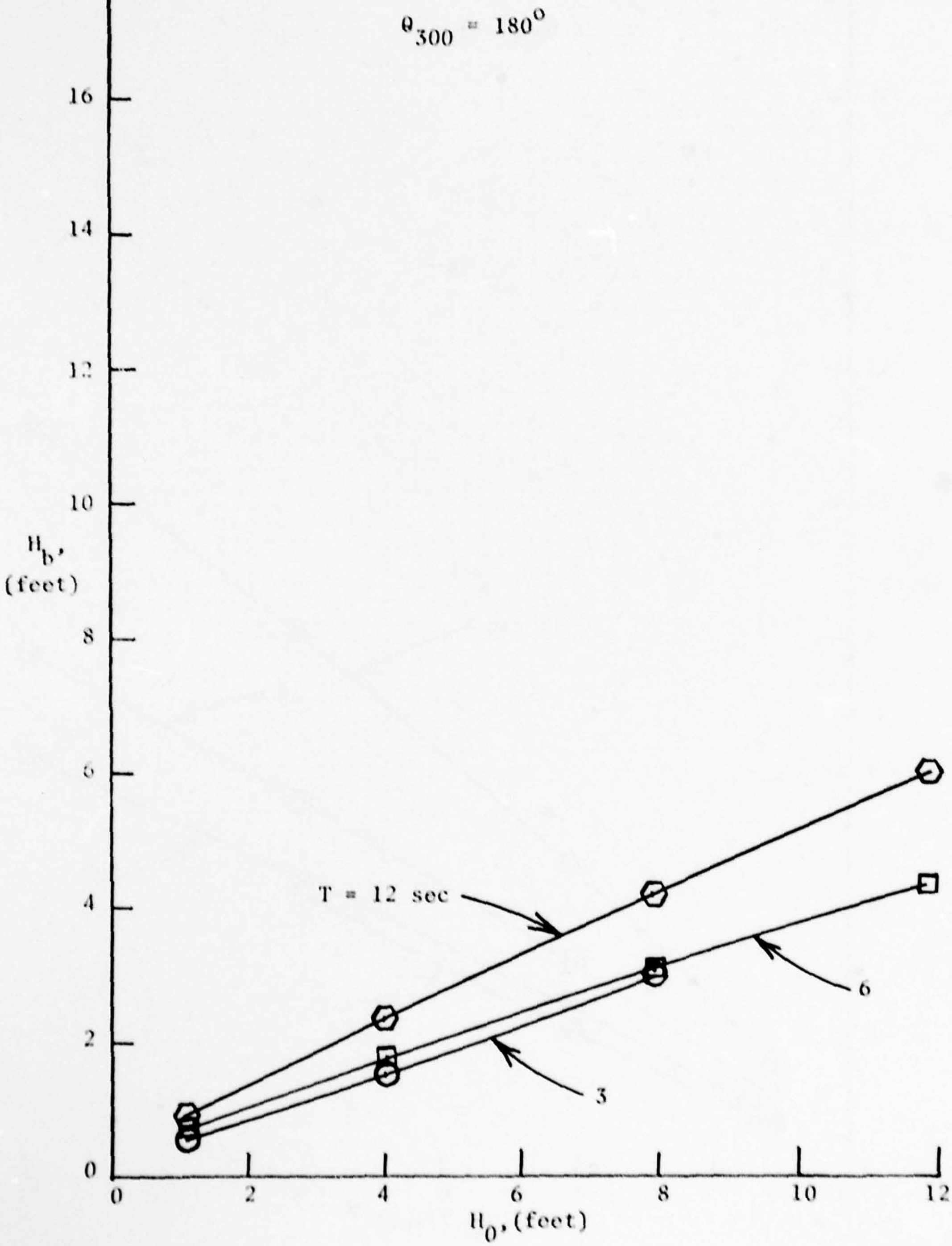

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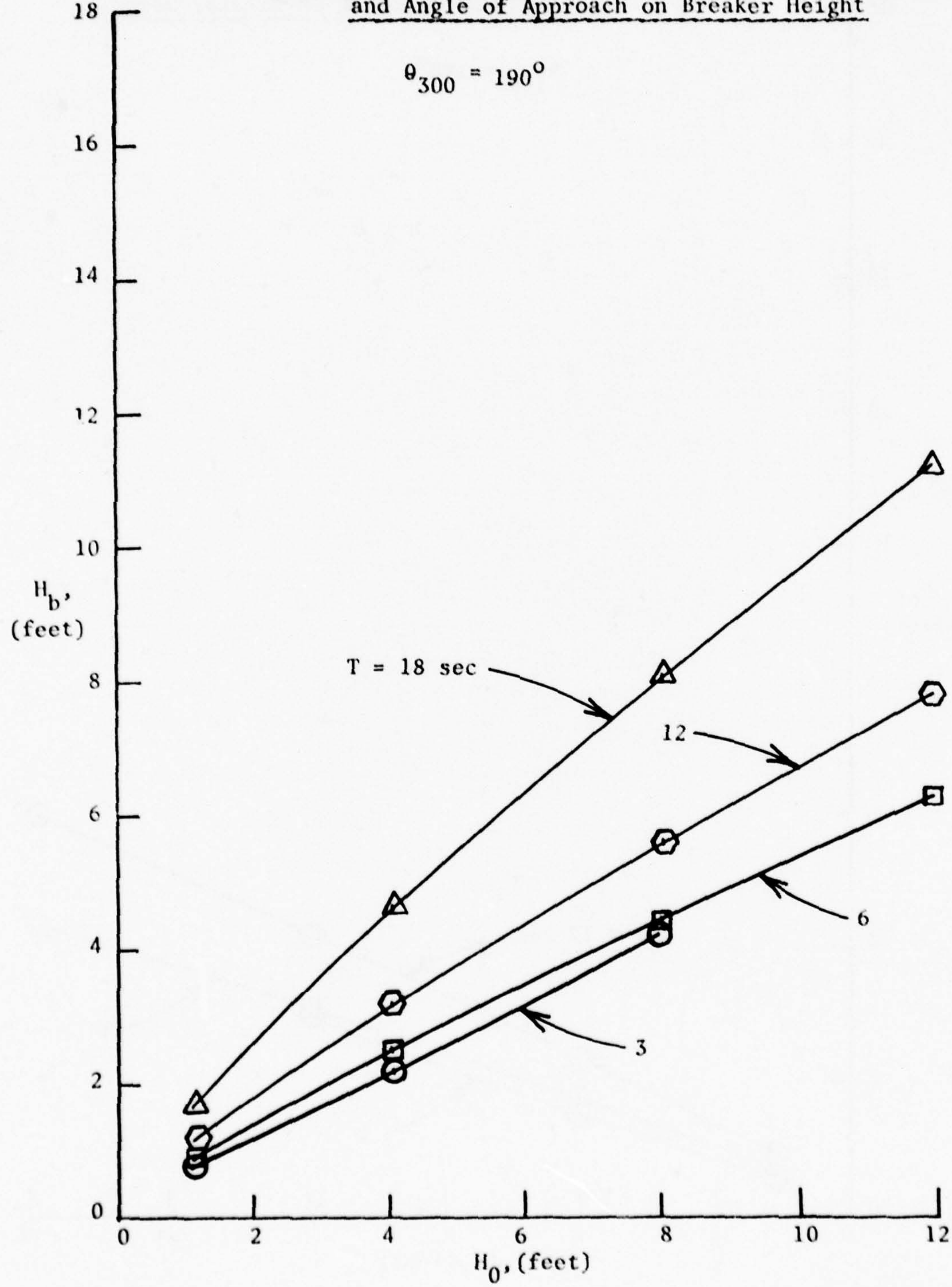

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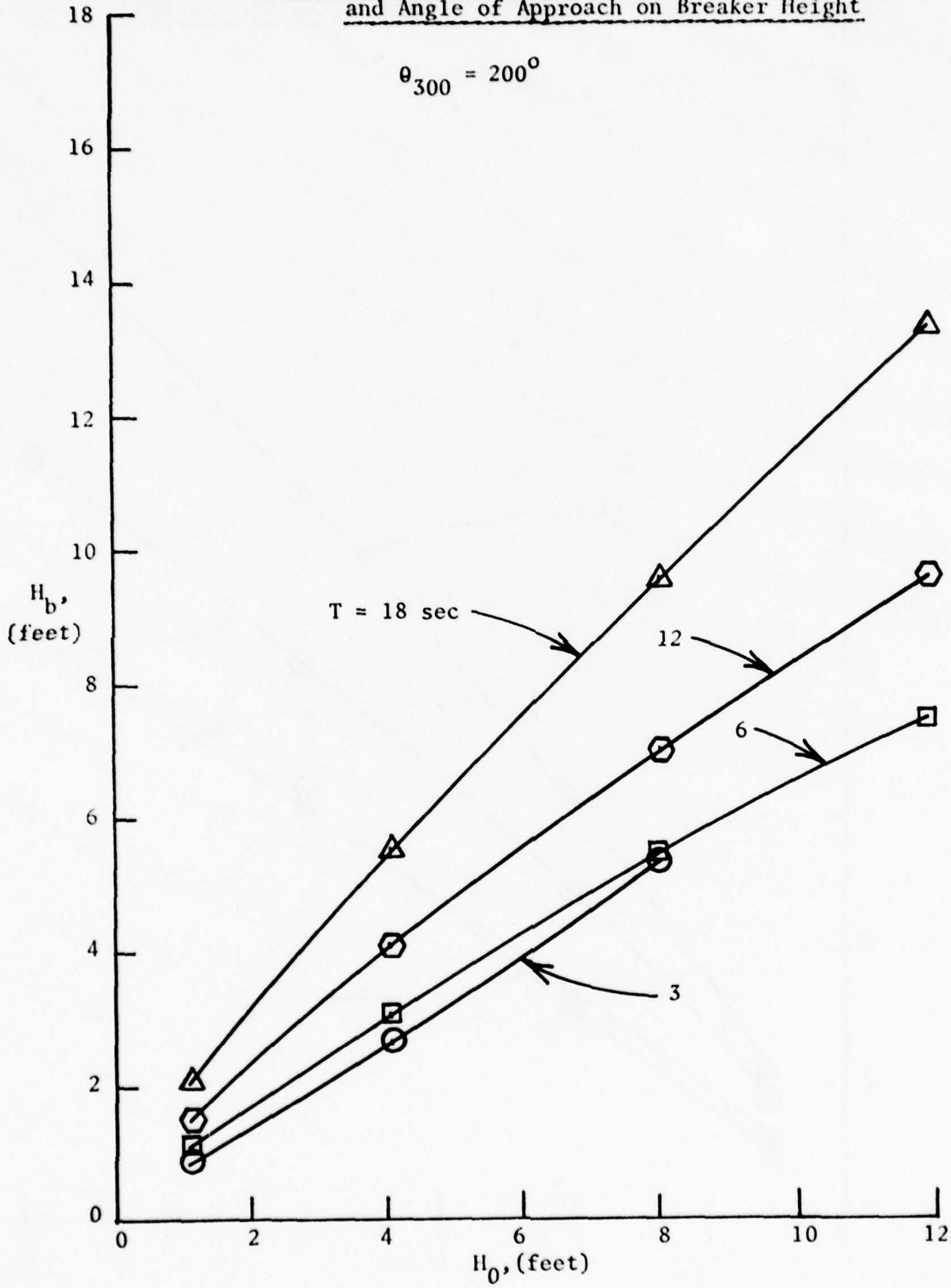

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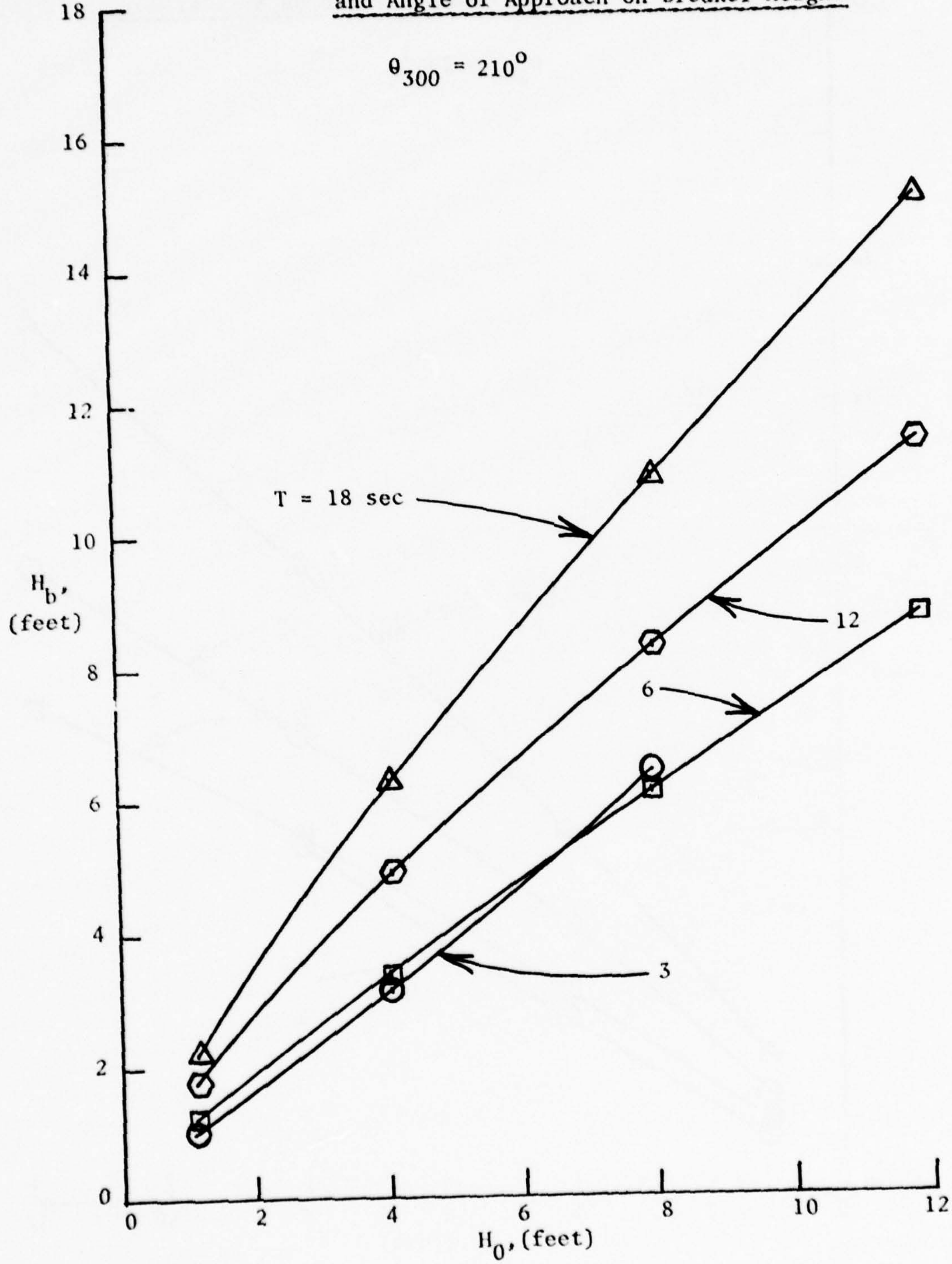

MISSION BAY, CALIFORNIA

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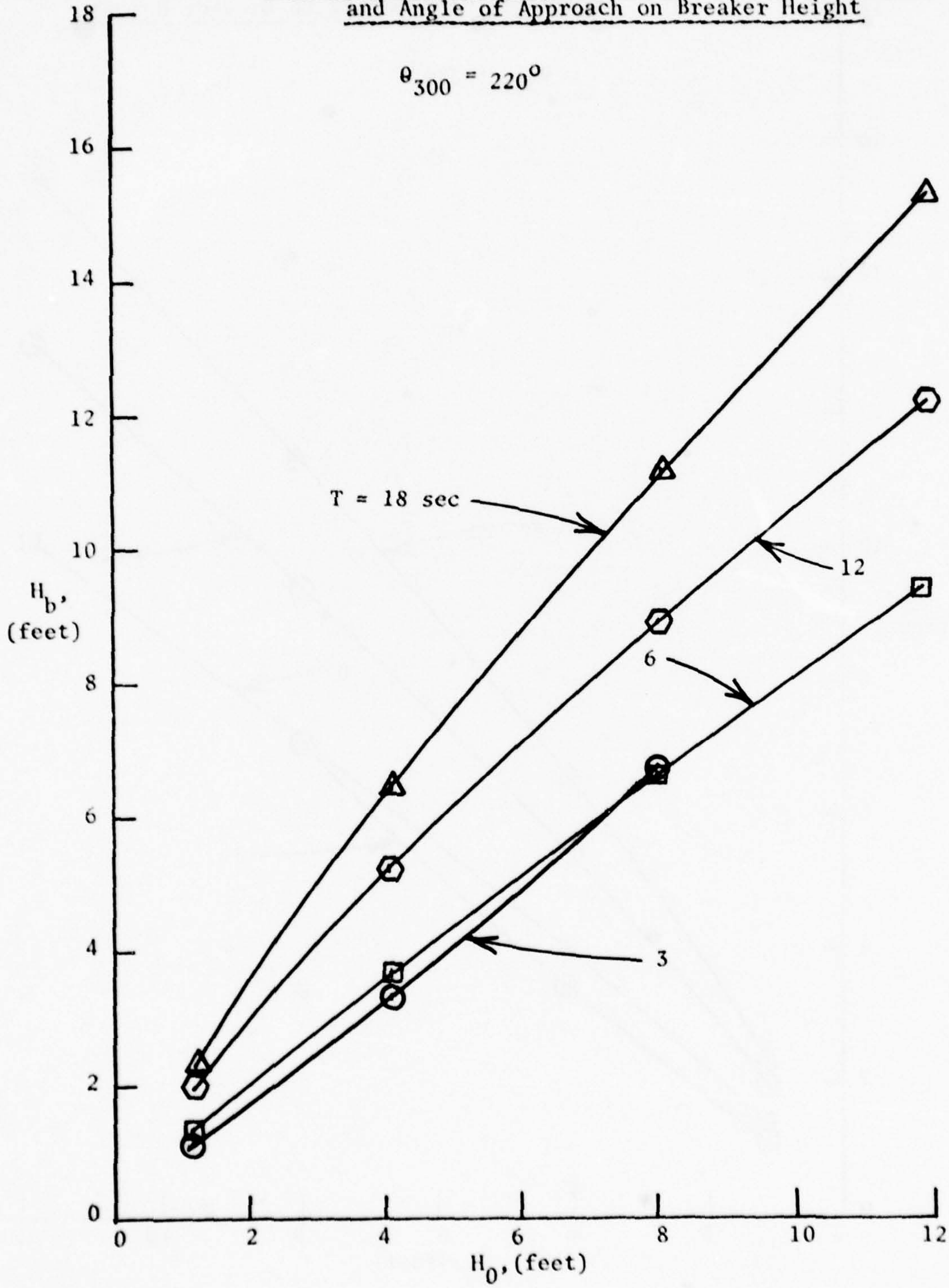

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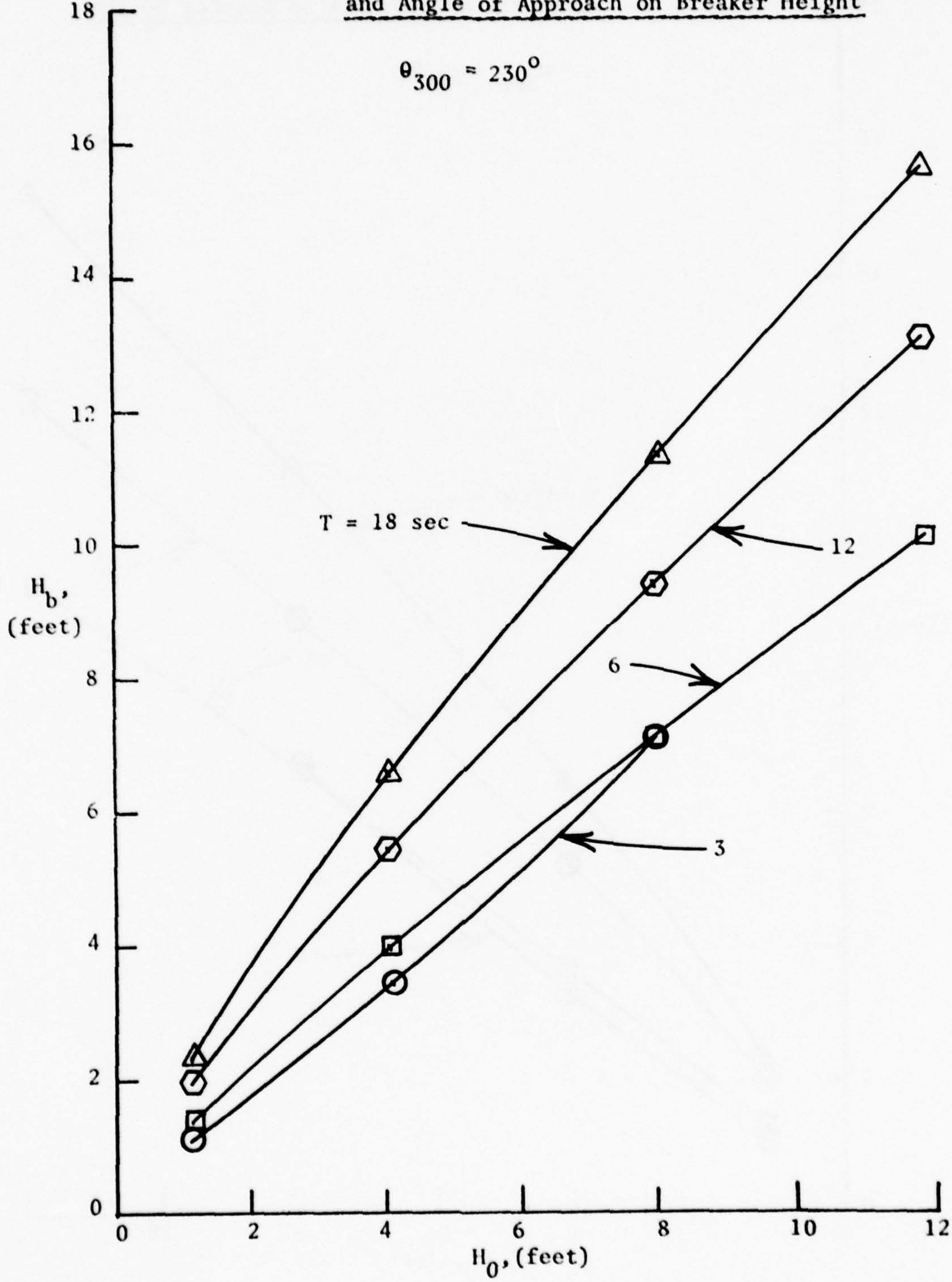
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Height



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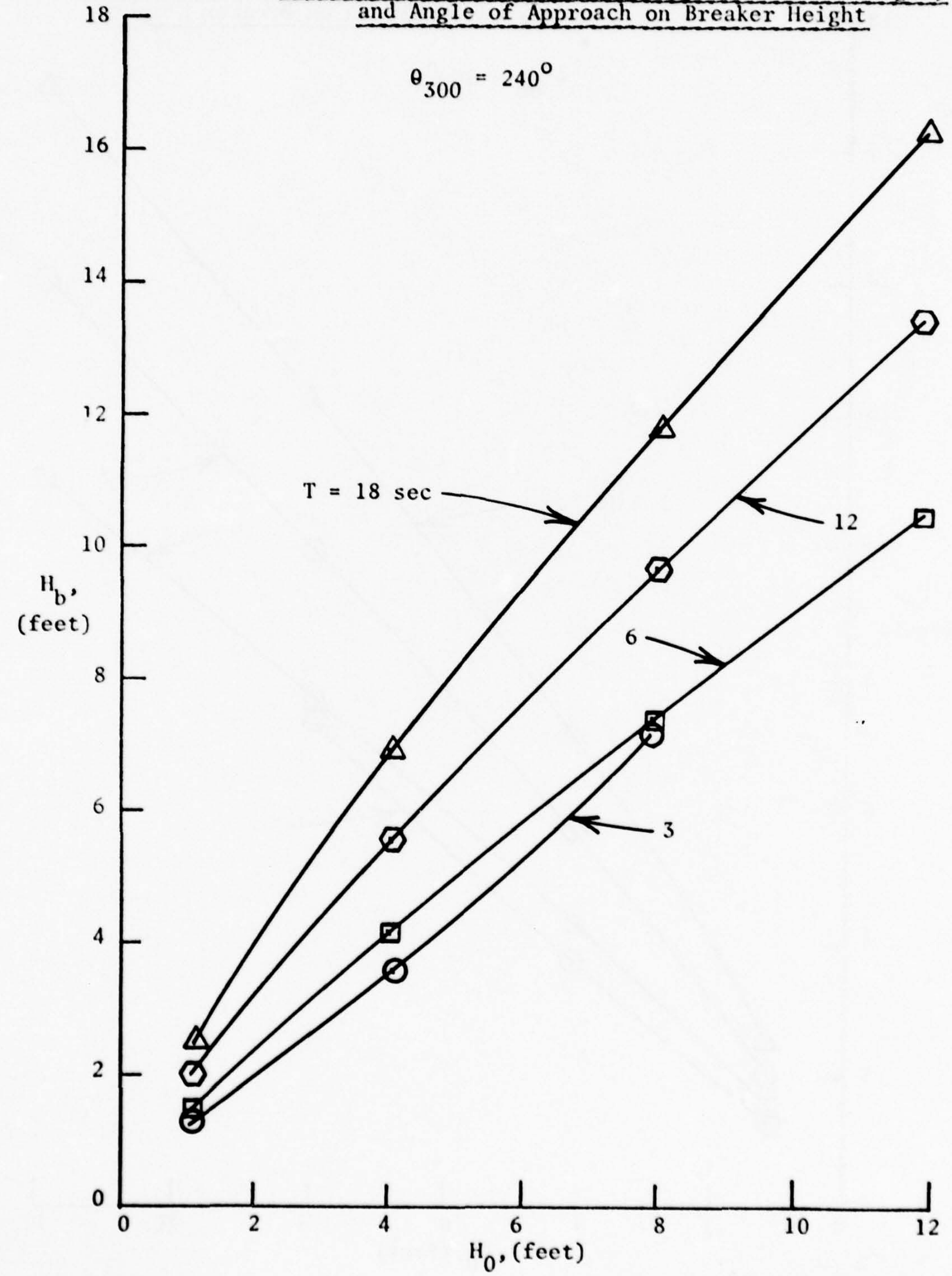

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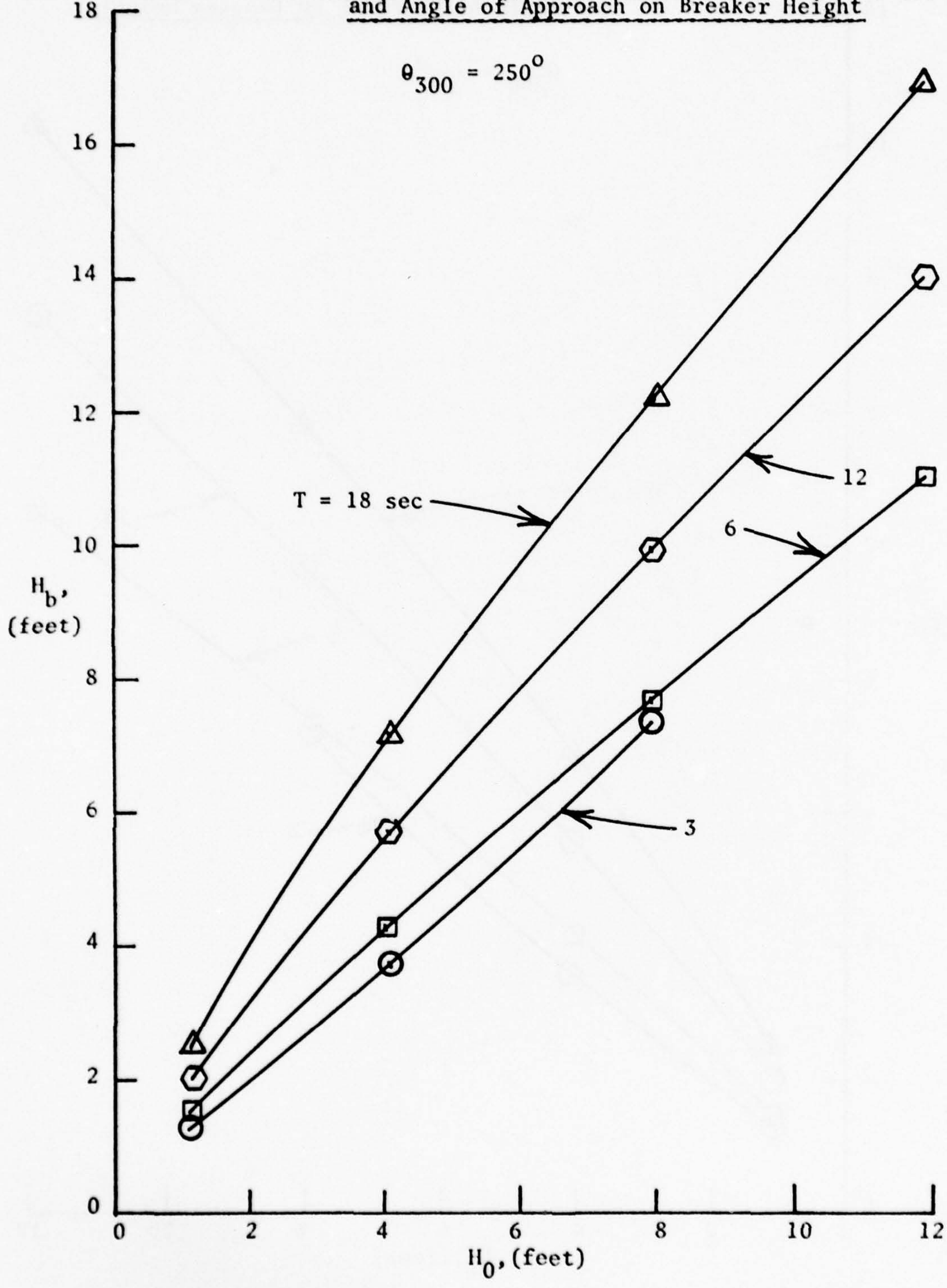
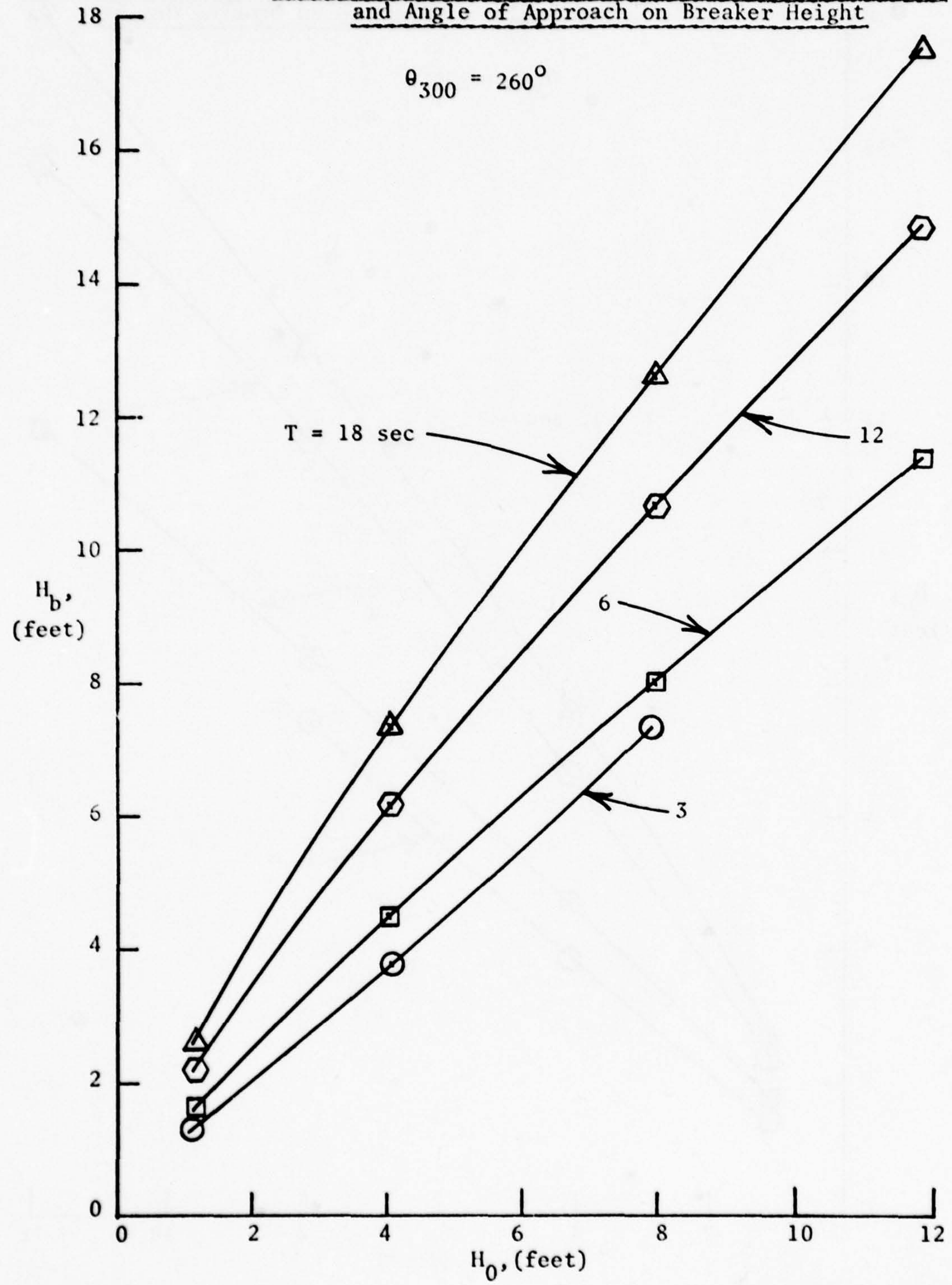


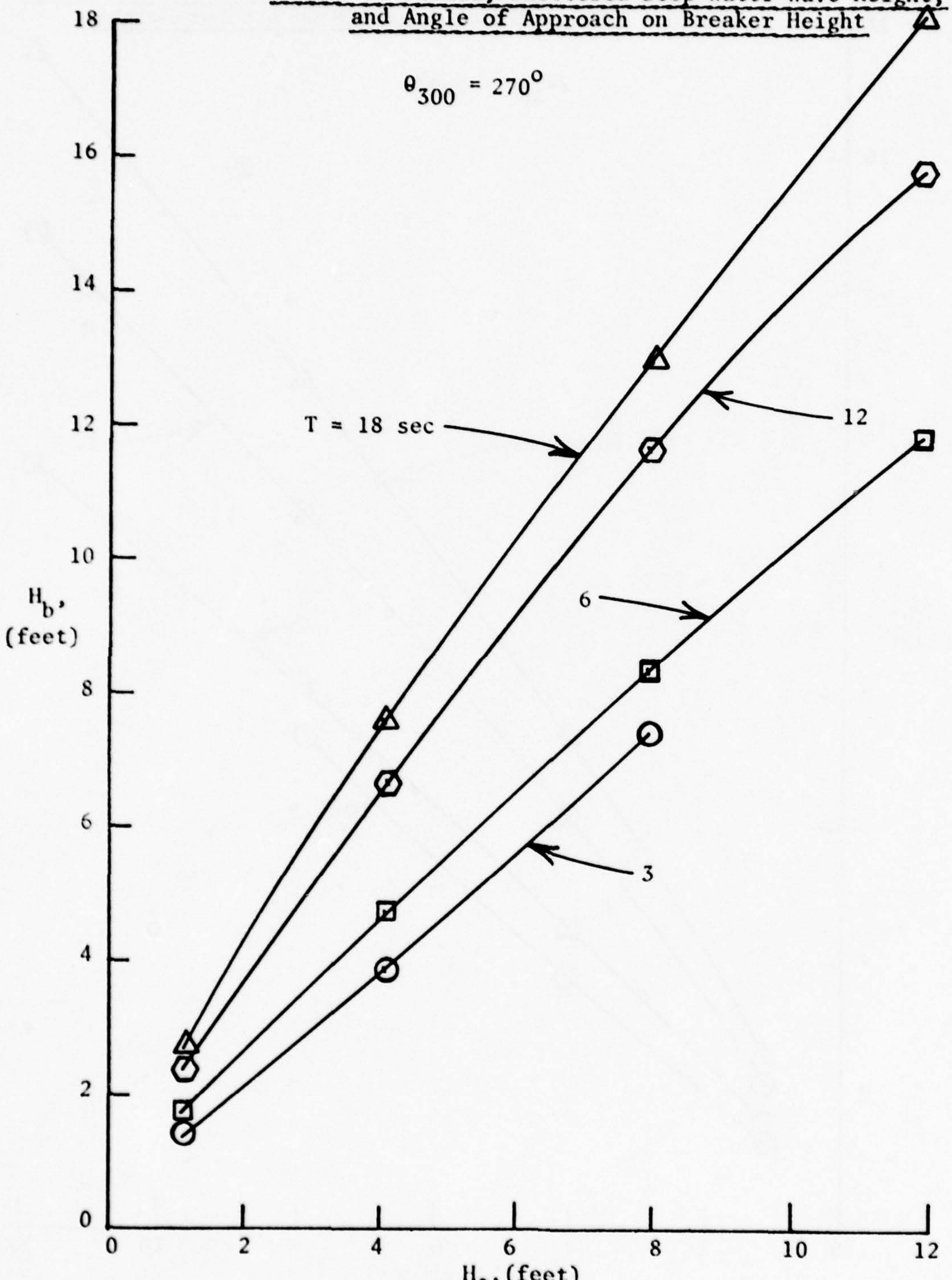
MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Height



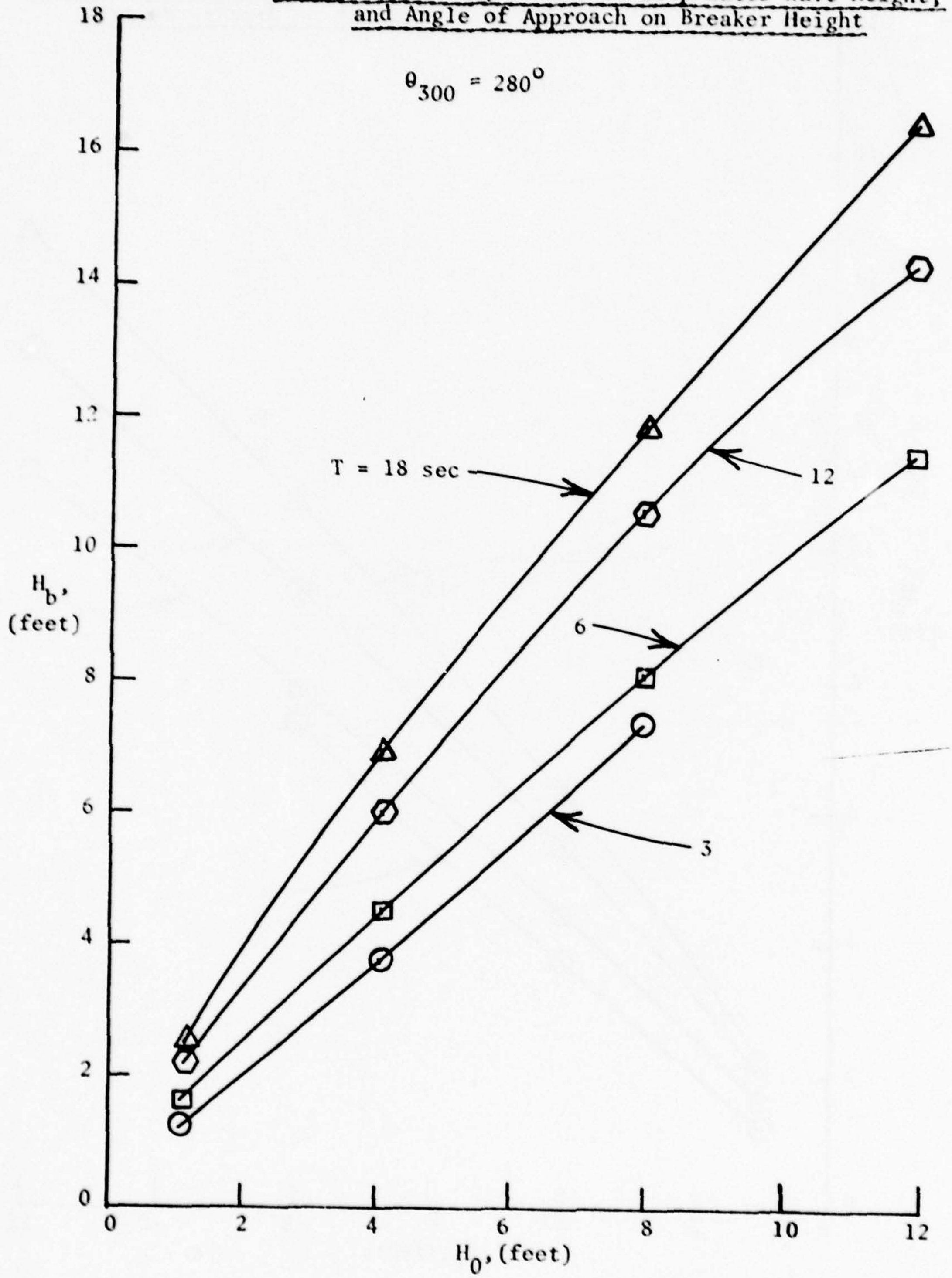
MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Height



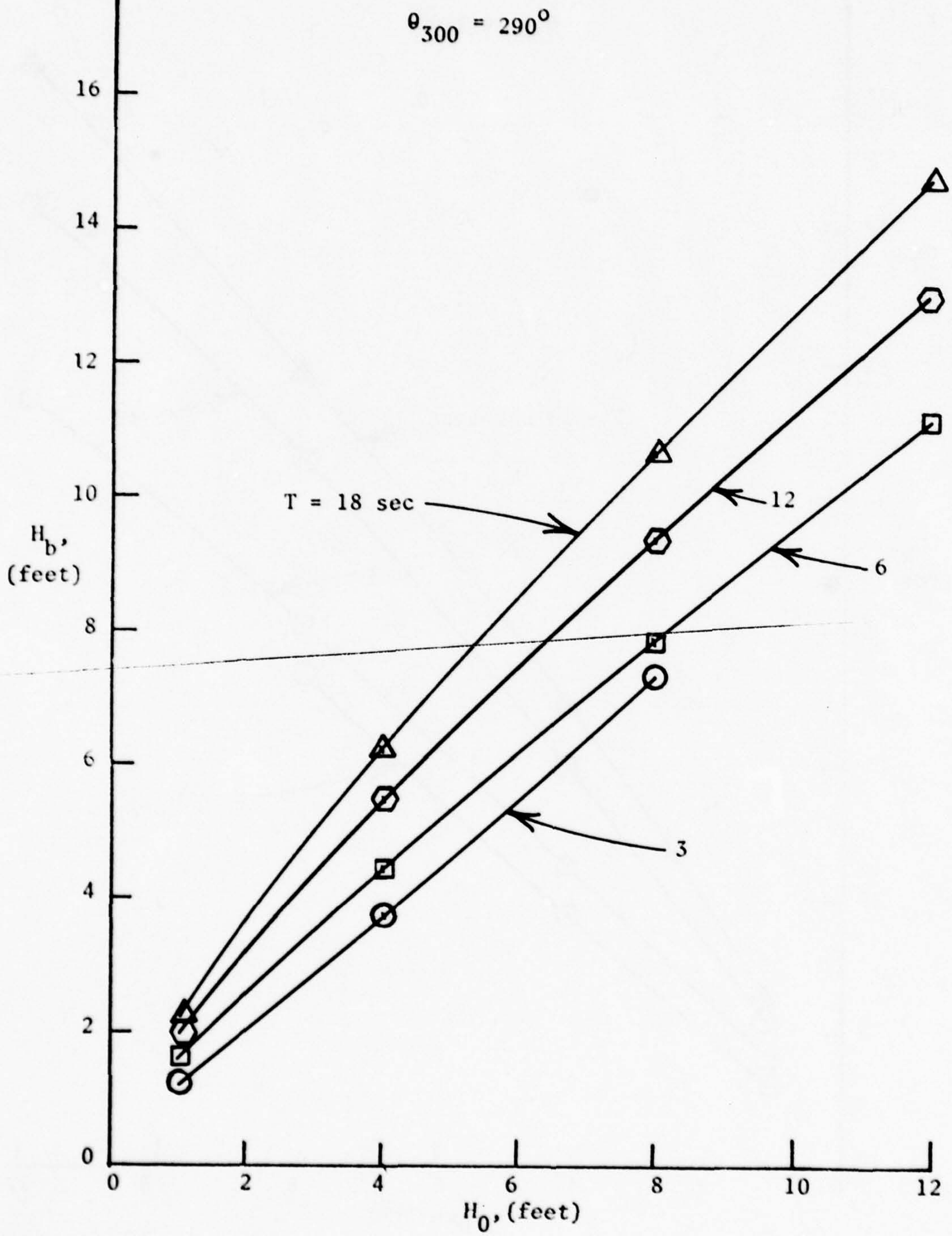
MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Height



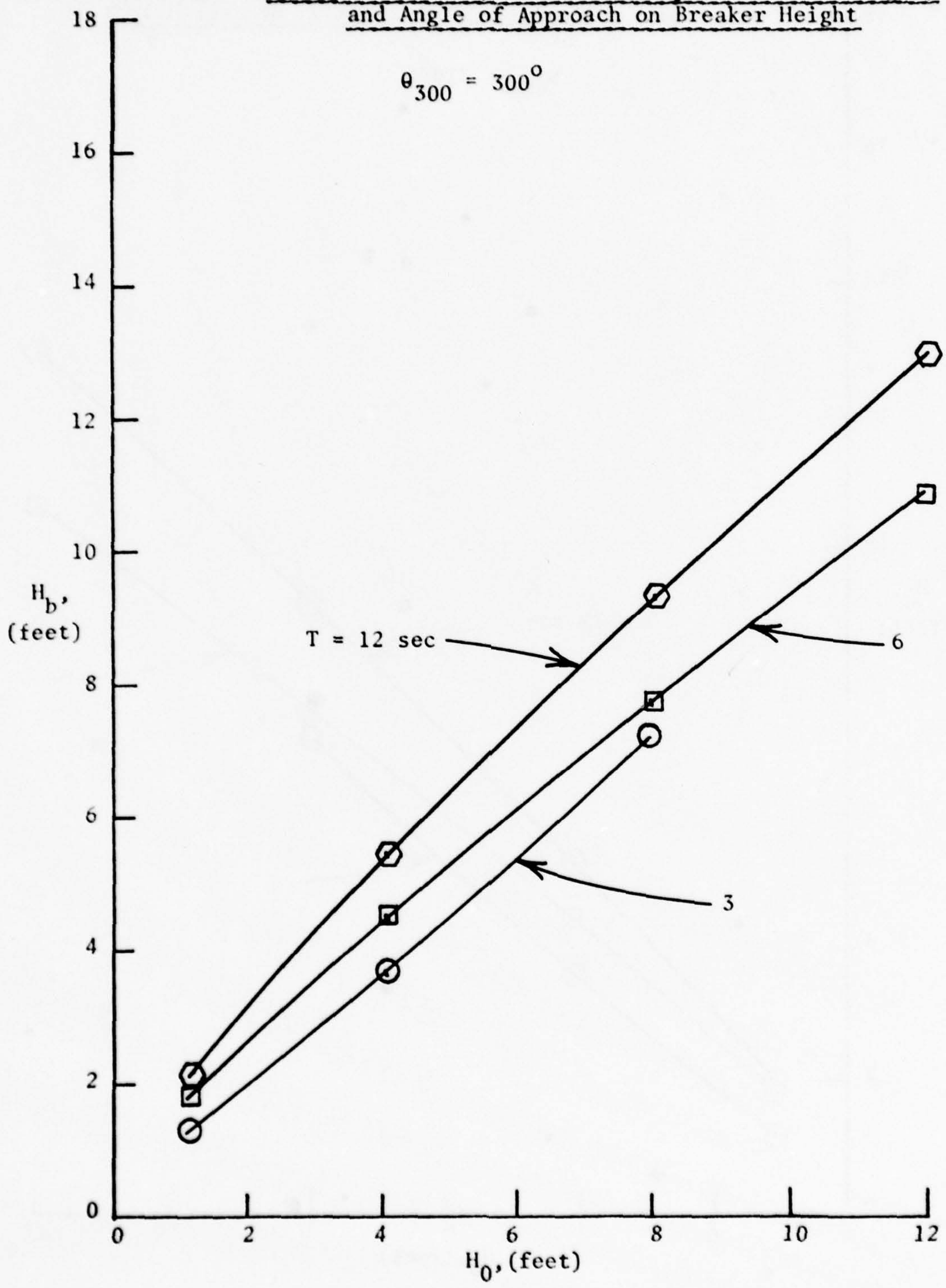
MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Height



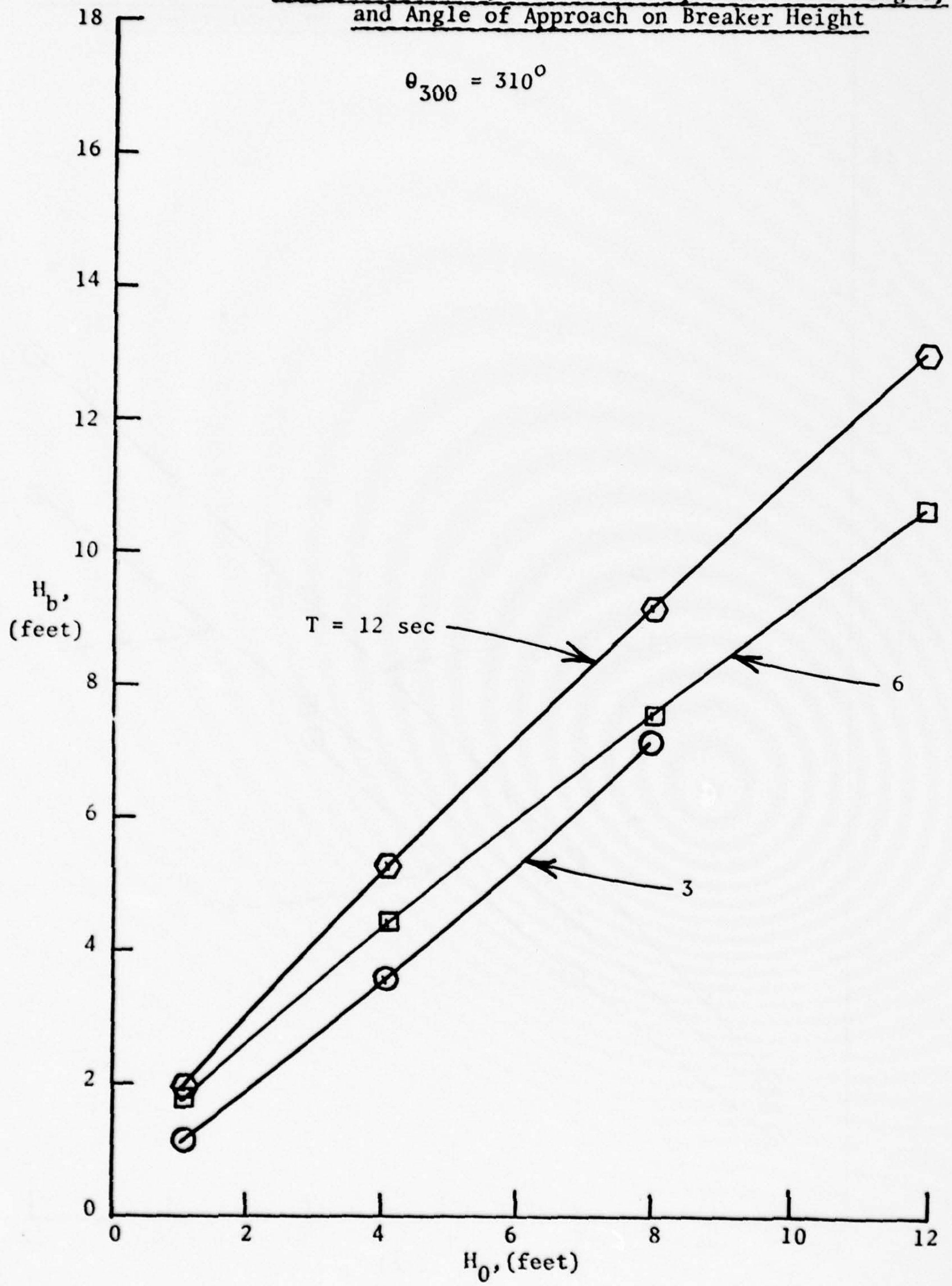
MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Height



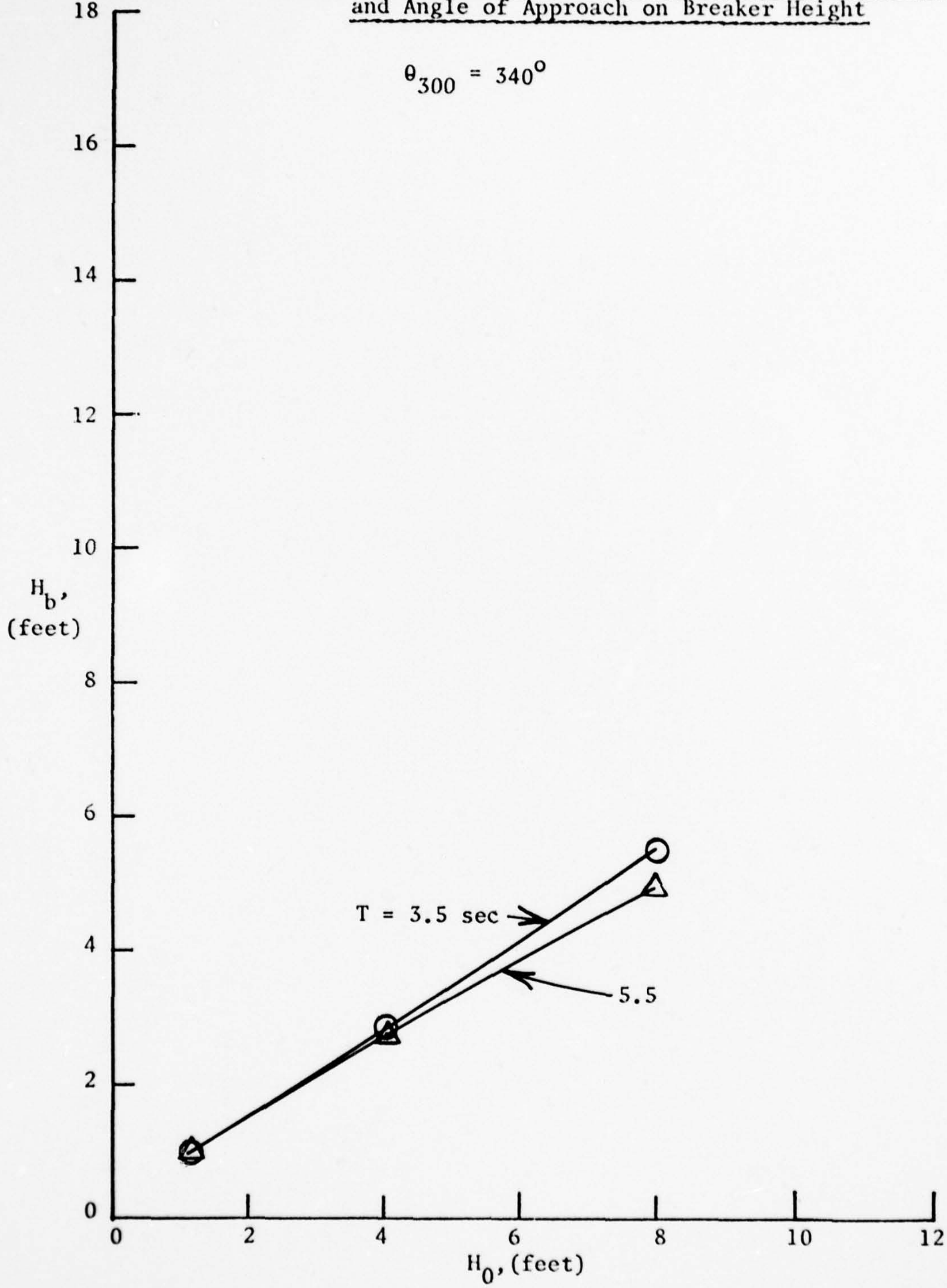
MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Height

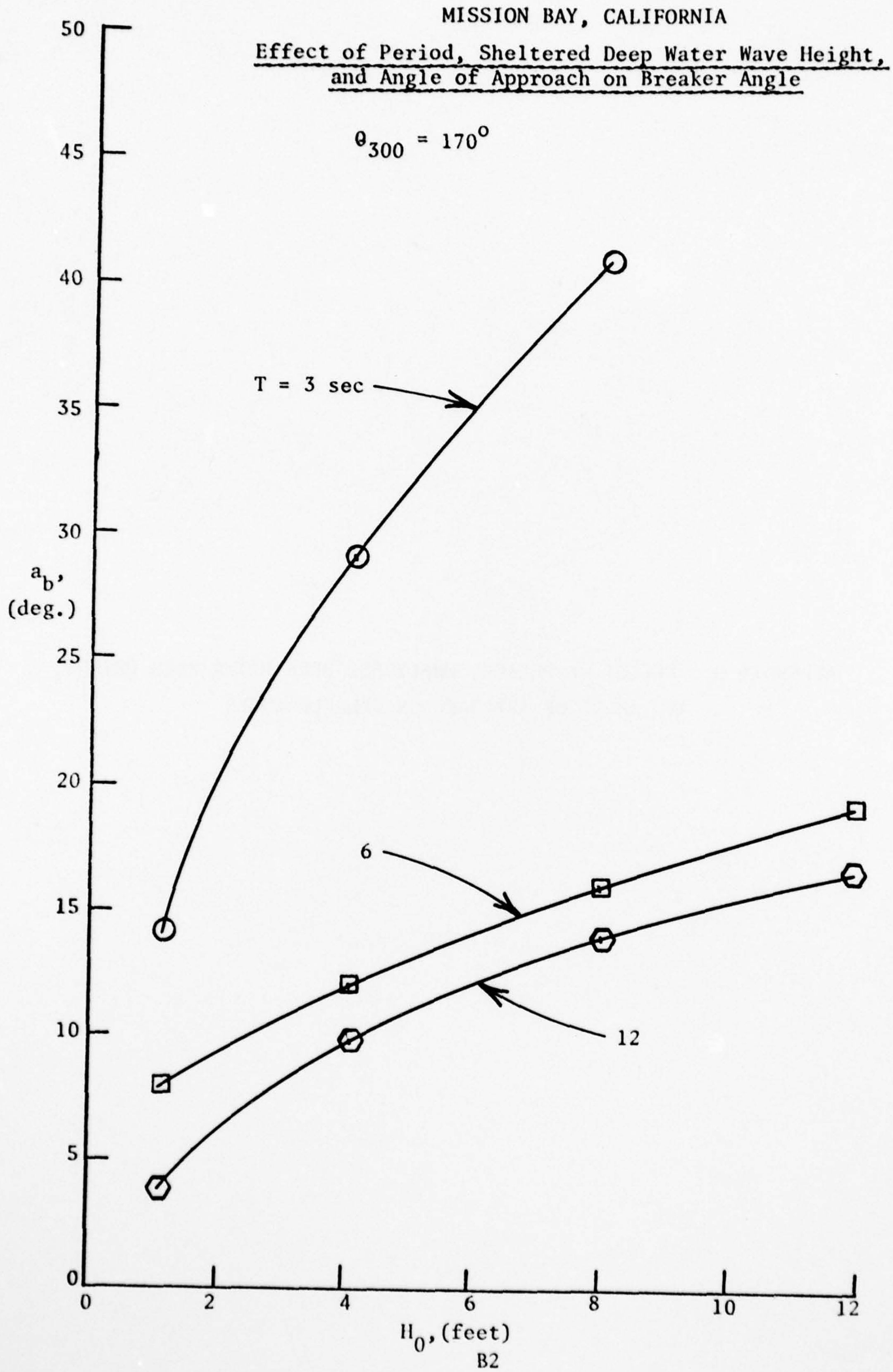


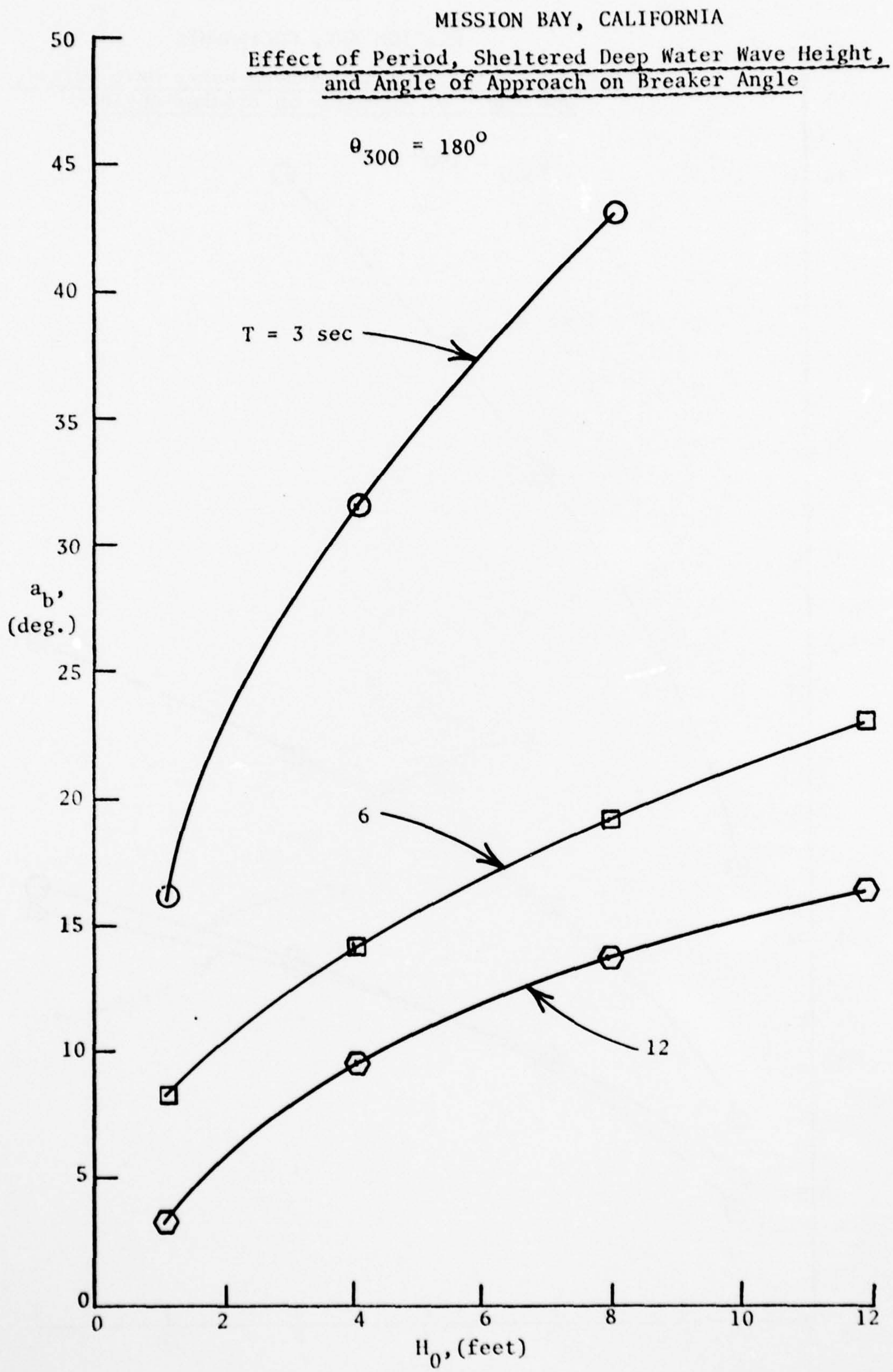
MISSION BAY, CALIFORNIA

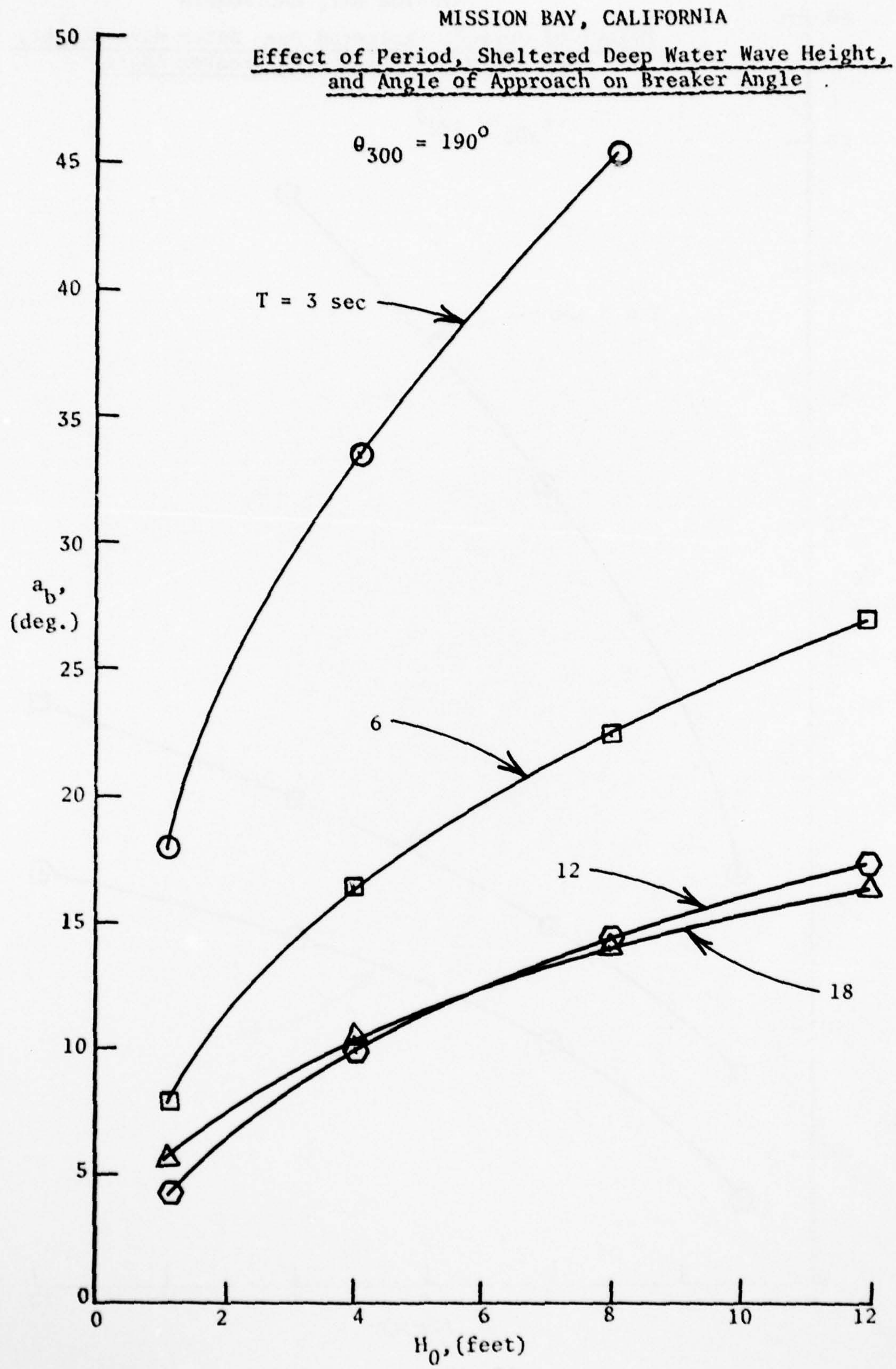
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Height



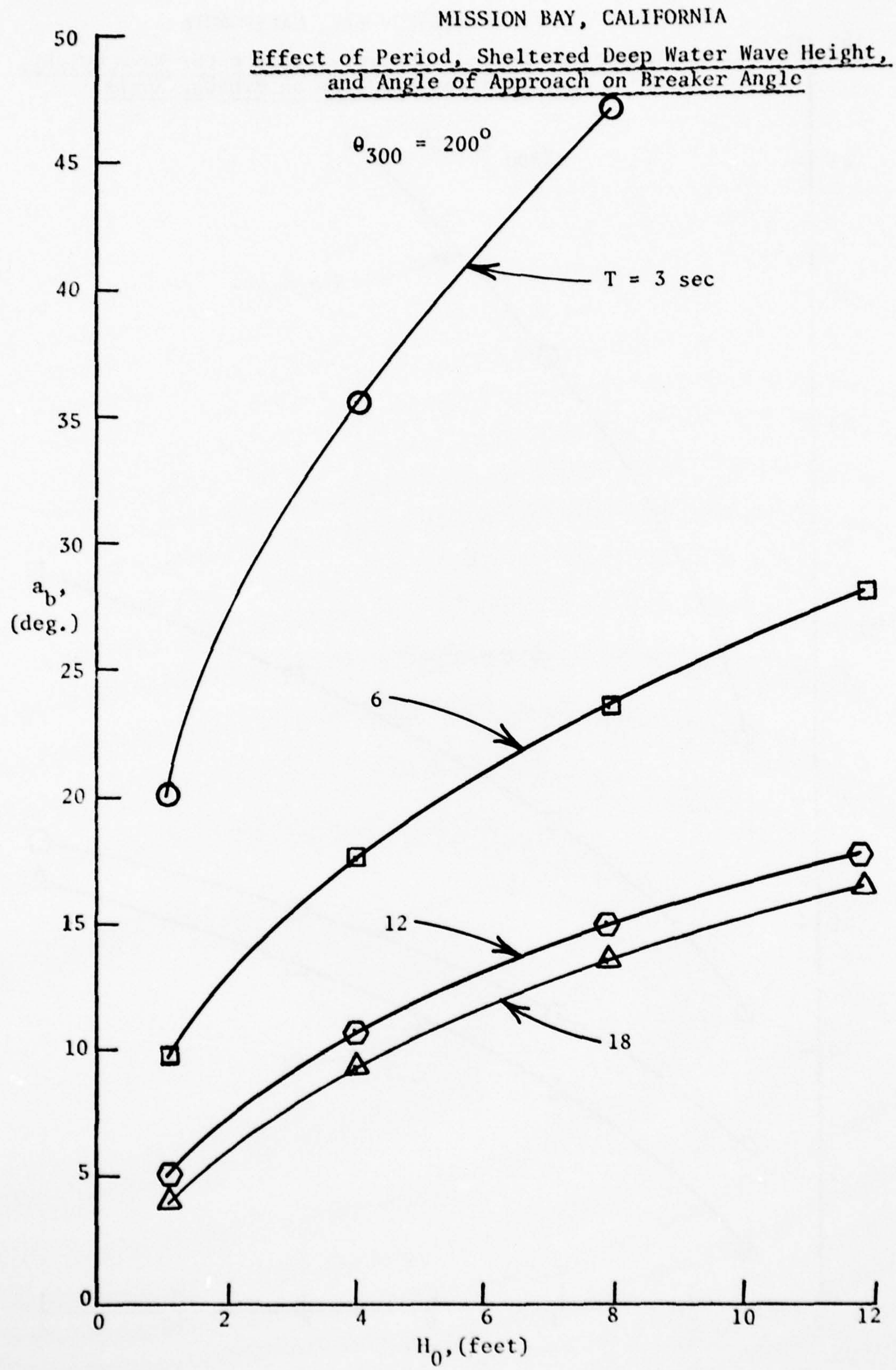
APPENDIX B: EFFECT OF PERIOD, SHELTERED DEEP WATER WAVE HEIGHT, AND ANGLE OF APPROACH ON BREAKER ANGLE

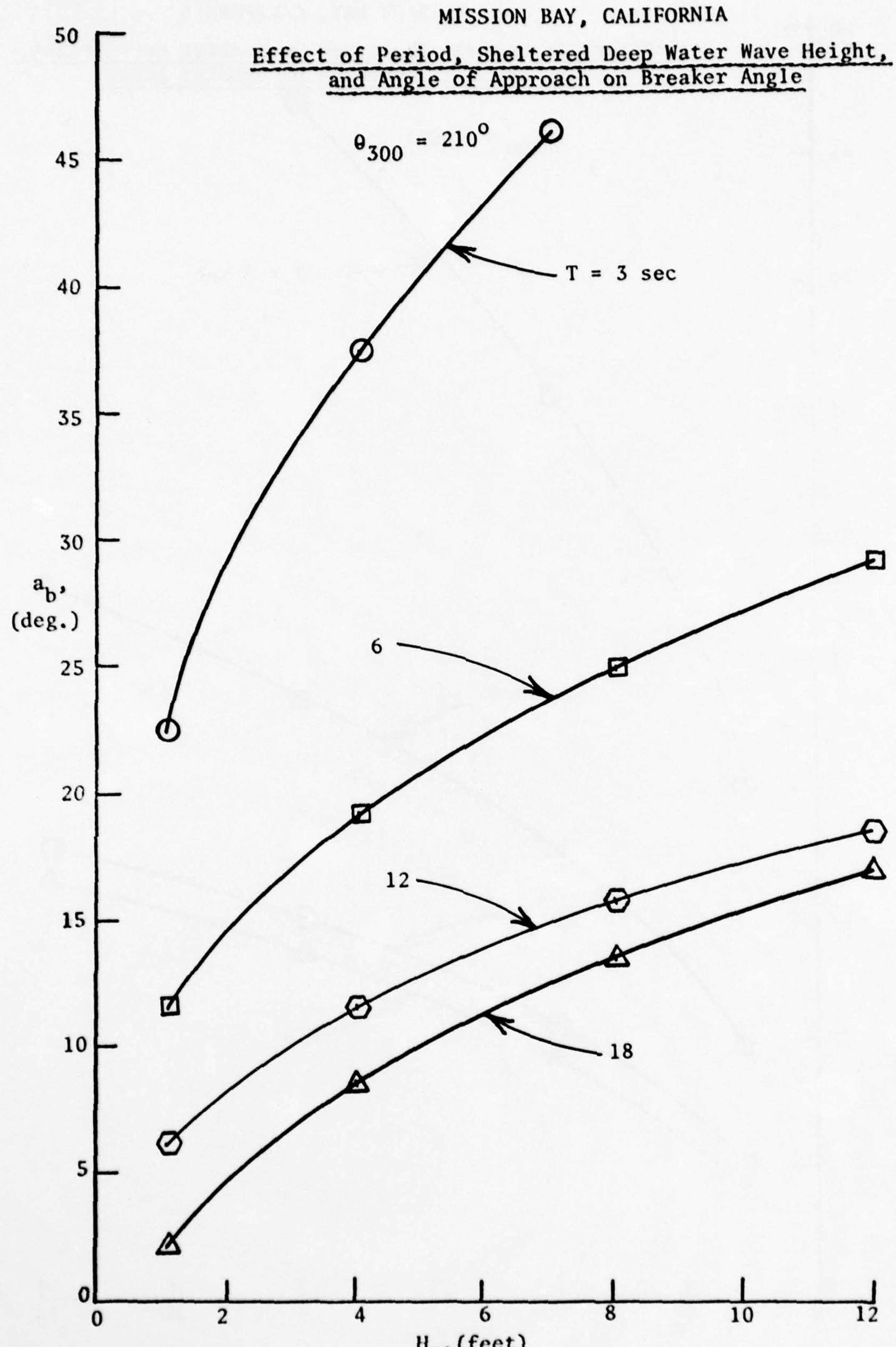

MISSION BAY, CALIFORNIA
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle
θ300 = 170°
T = 3 sec
6
12
ab, (deg.)
H0, (feet)
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10
12

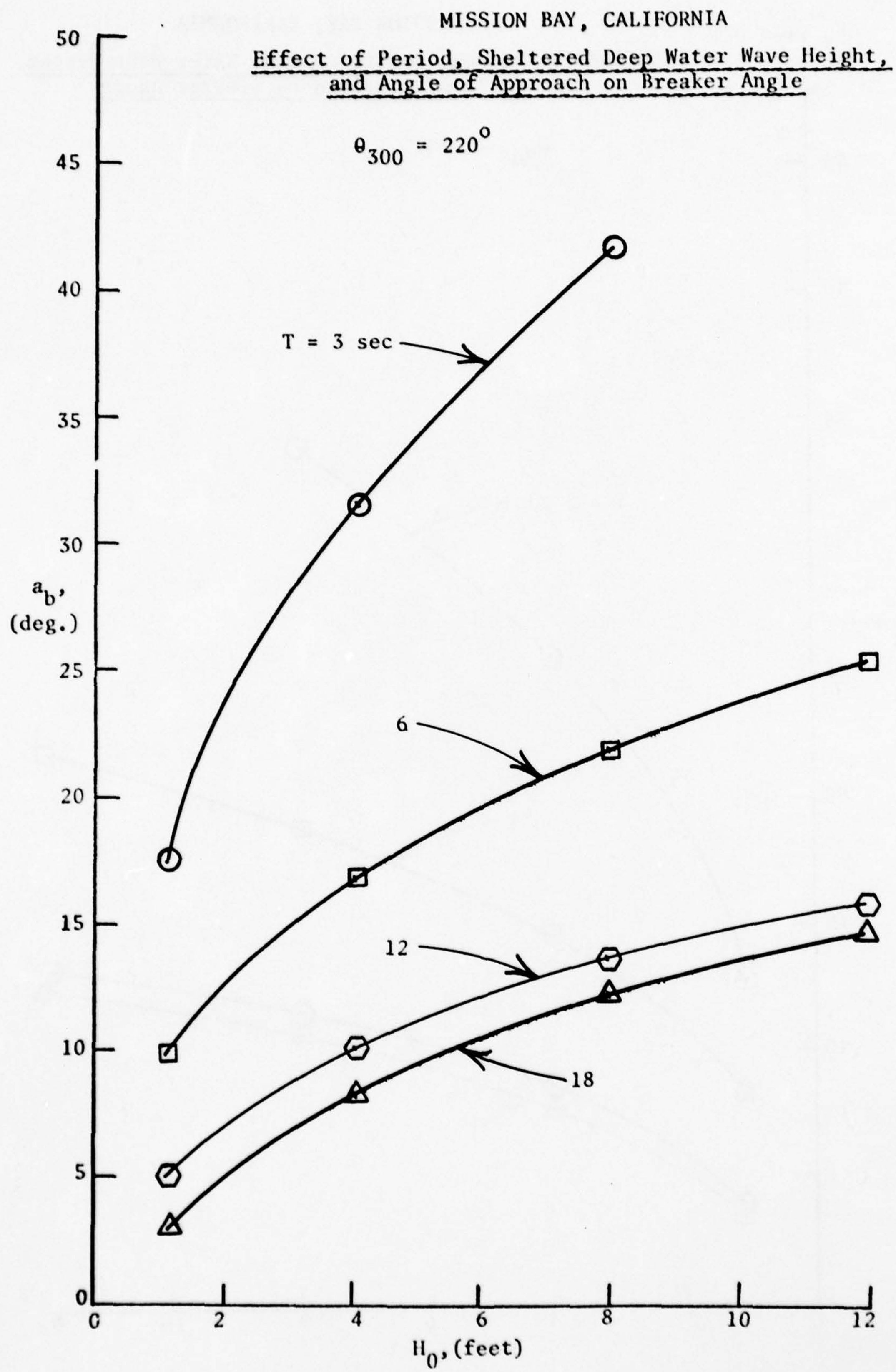

MISSION BAY, CALIFORNIA
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle
θ300 = 180°
T = 3 sec
6
12
a_b, (deg.)
H_0, (feet)
0
2
4
6
8
10
12
5
10
15
20
25
30
35
40
45
50

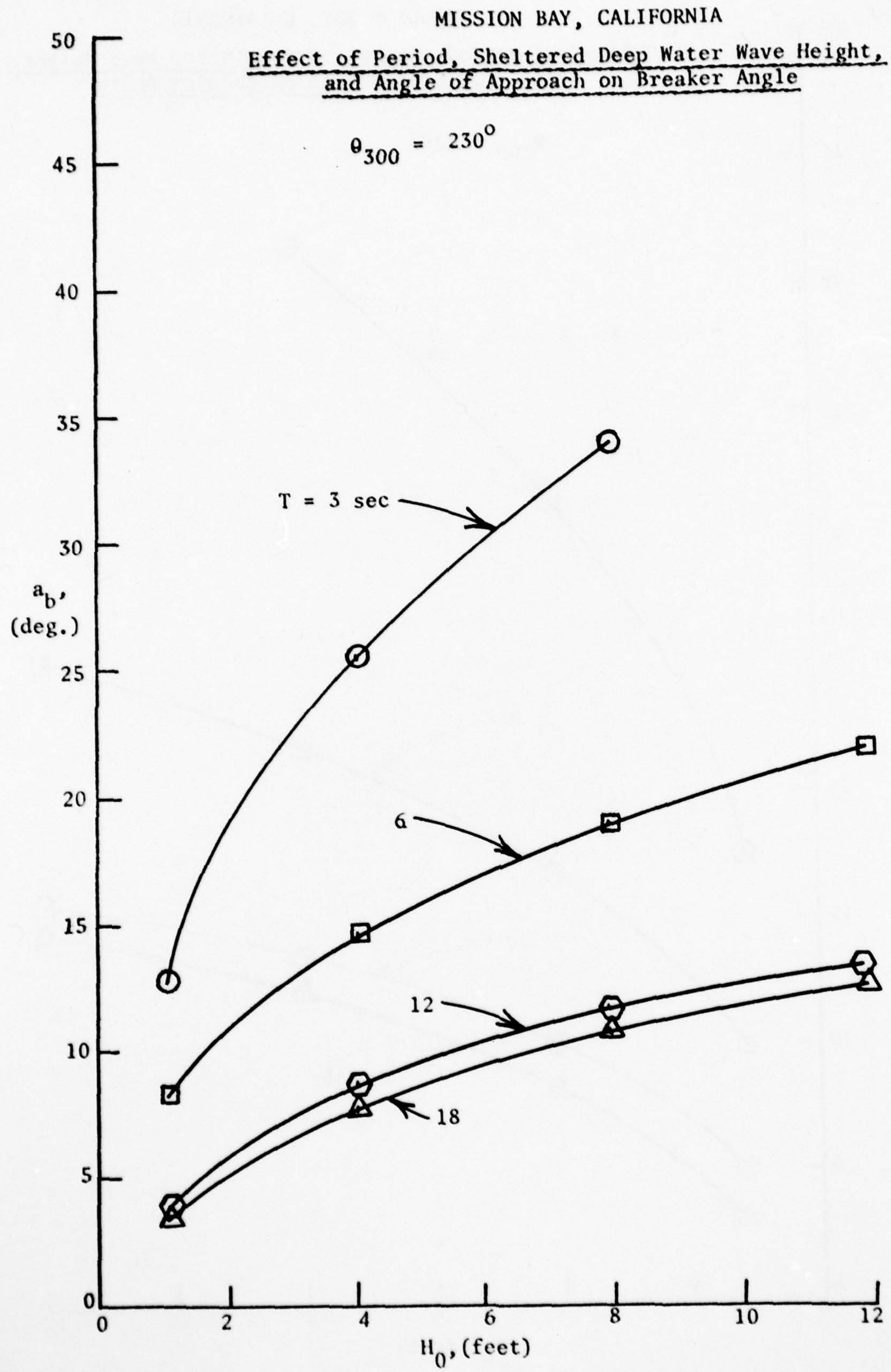


MISSION BAY, CALIFORNIA
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle
θ300 = 190°
T = 3 sec
6
12
18
ab, (deg.)
50
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
H0, (feet)


MISSION BAY, CALIFORNIA
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle
$\theta_{300} = 200^o$
T = 3 sec
6
12
18
a_b, (deg.)
H_0, (feet)
0
2
4
6
8
10
12
5
15
20
25
30
35
40
45
50

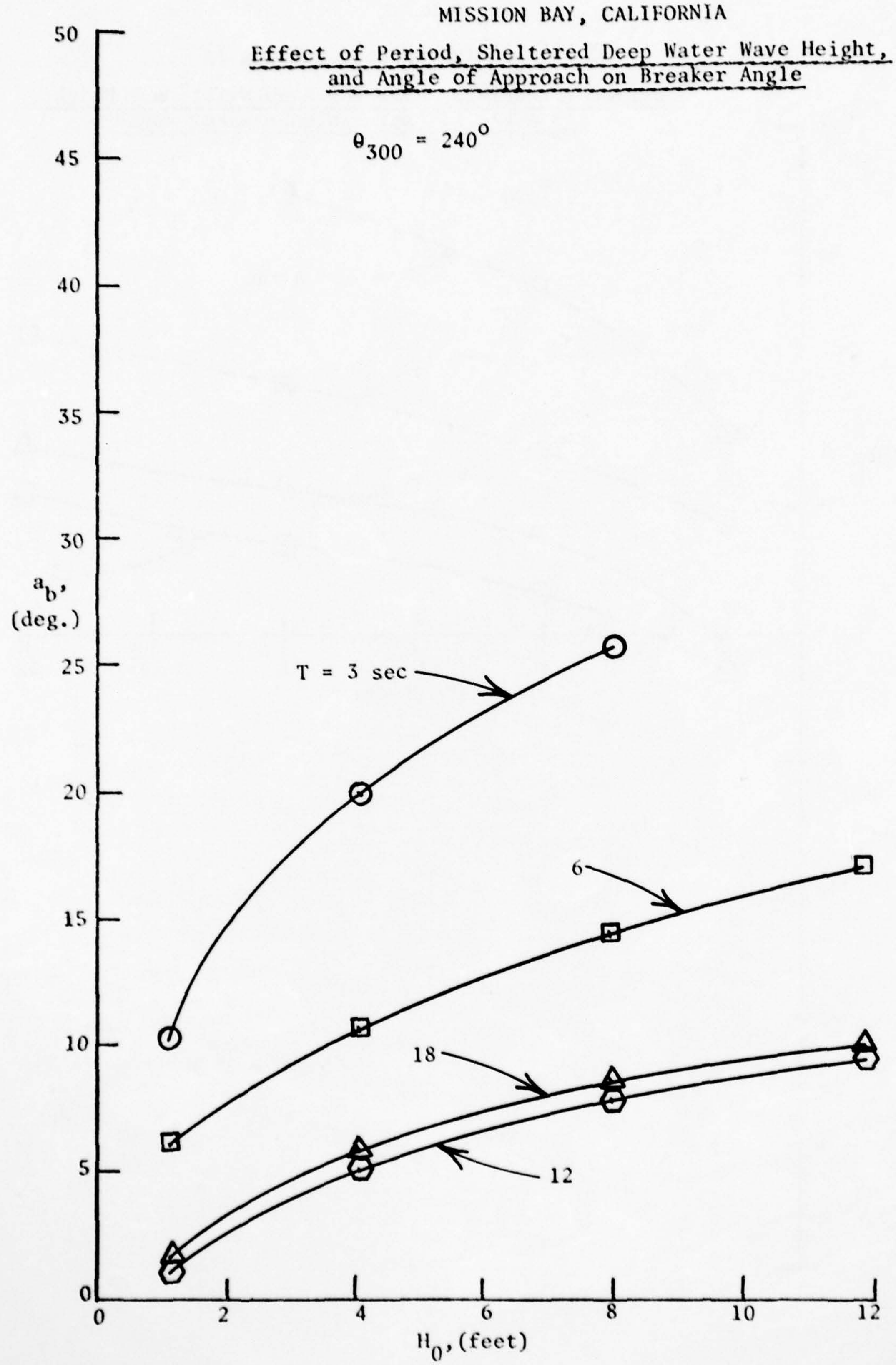

MISSION BAY, CALIFORNIA
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle
θ300 = 210°
T = 3 sec
6
12
18
ab, (deg.)
H0, (feet)
0
5
10
15
20
25
30
35
40
45
50
2
4
6
8
10
12


MISSION BAY, CALIFORNIA
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle
θ300 = 220°
T = 3 sec
6
12
18
ab, (deg.)
H0, (feet)
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10
12


MISSION BAY, CALIFORNIA
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle
$\theta_{300} = 230^{\circ}$
T = 3 sec
6
12
18
a_b, (deg.)
H_0, (feet)
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10
12

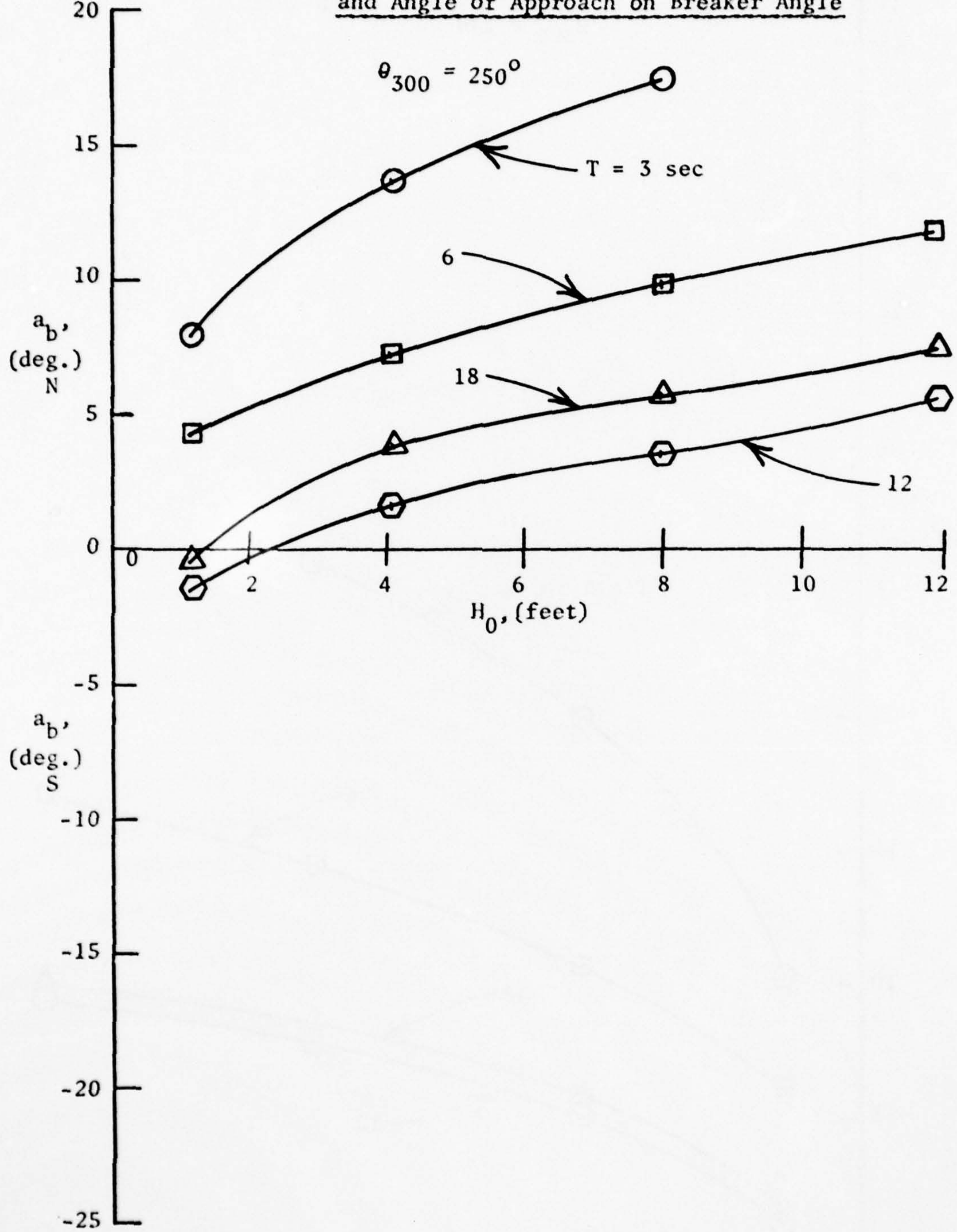
MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle



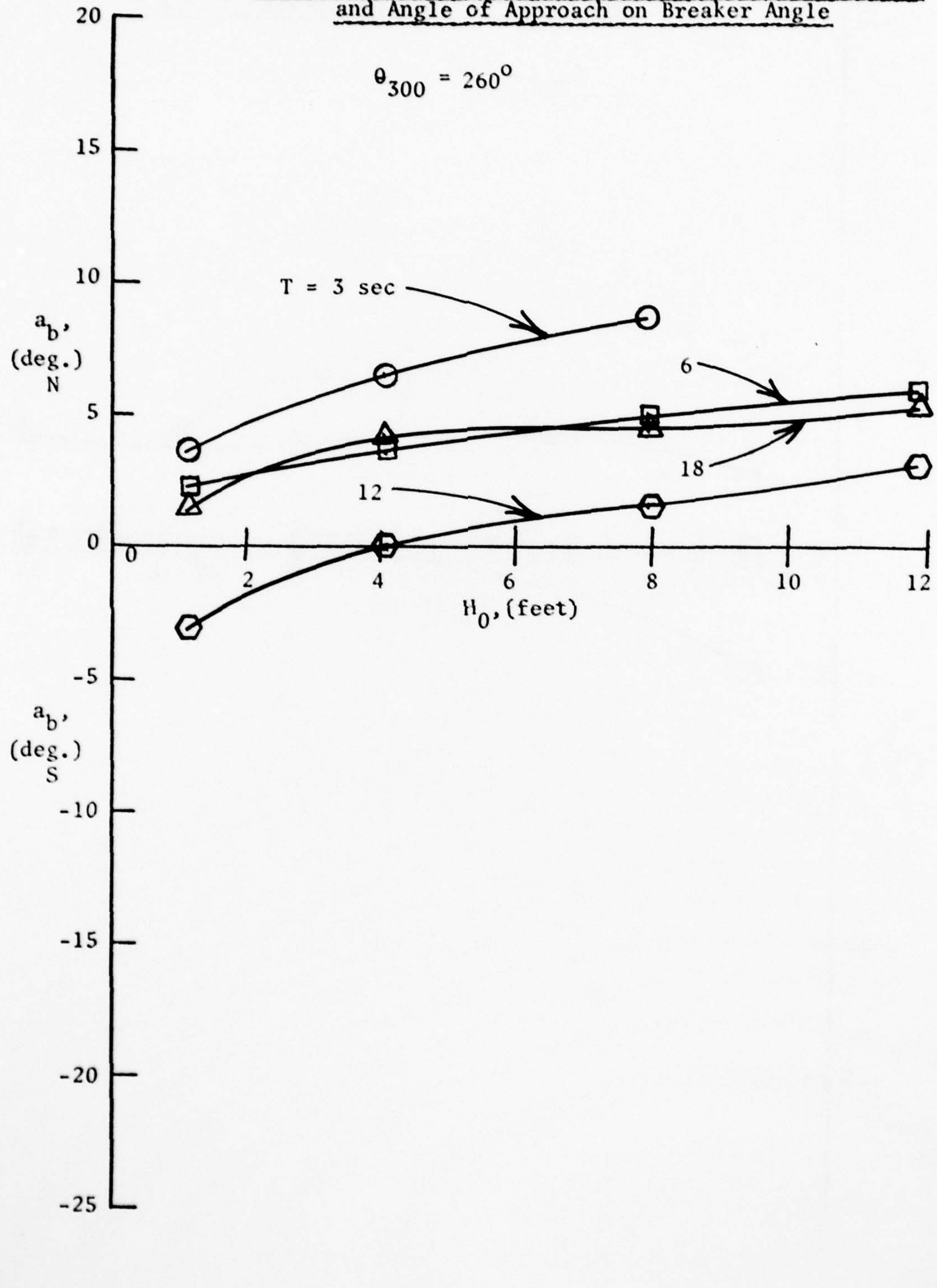
MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle



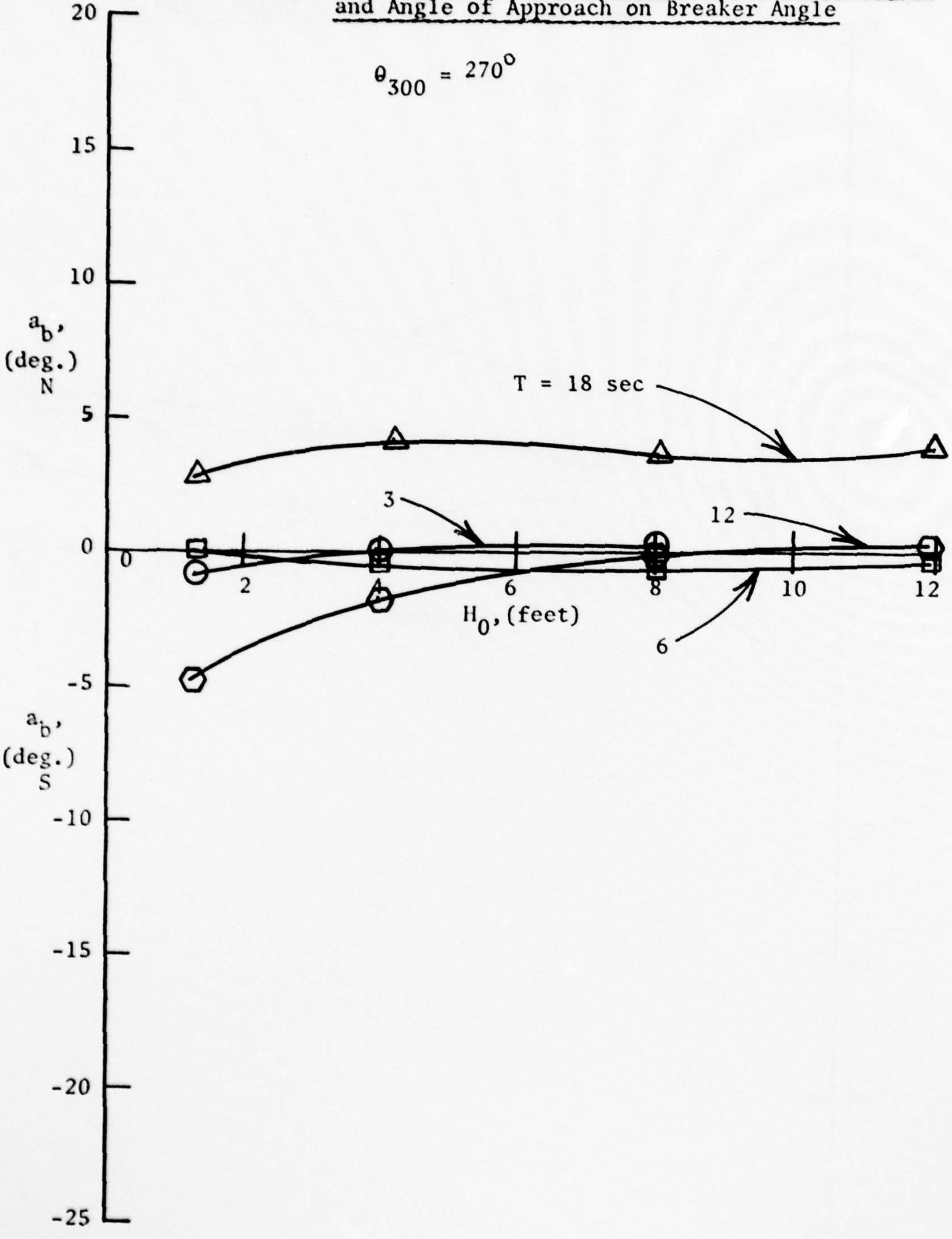
MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle



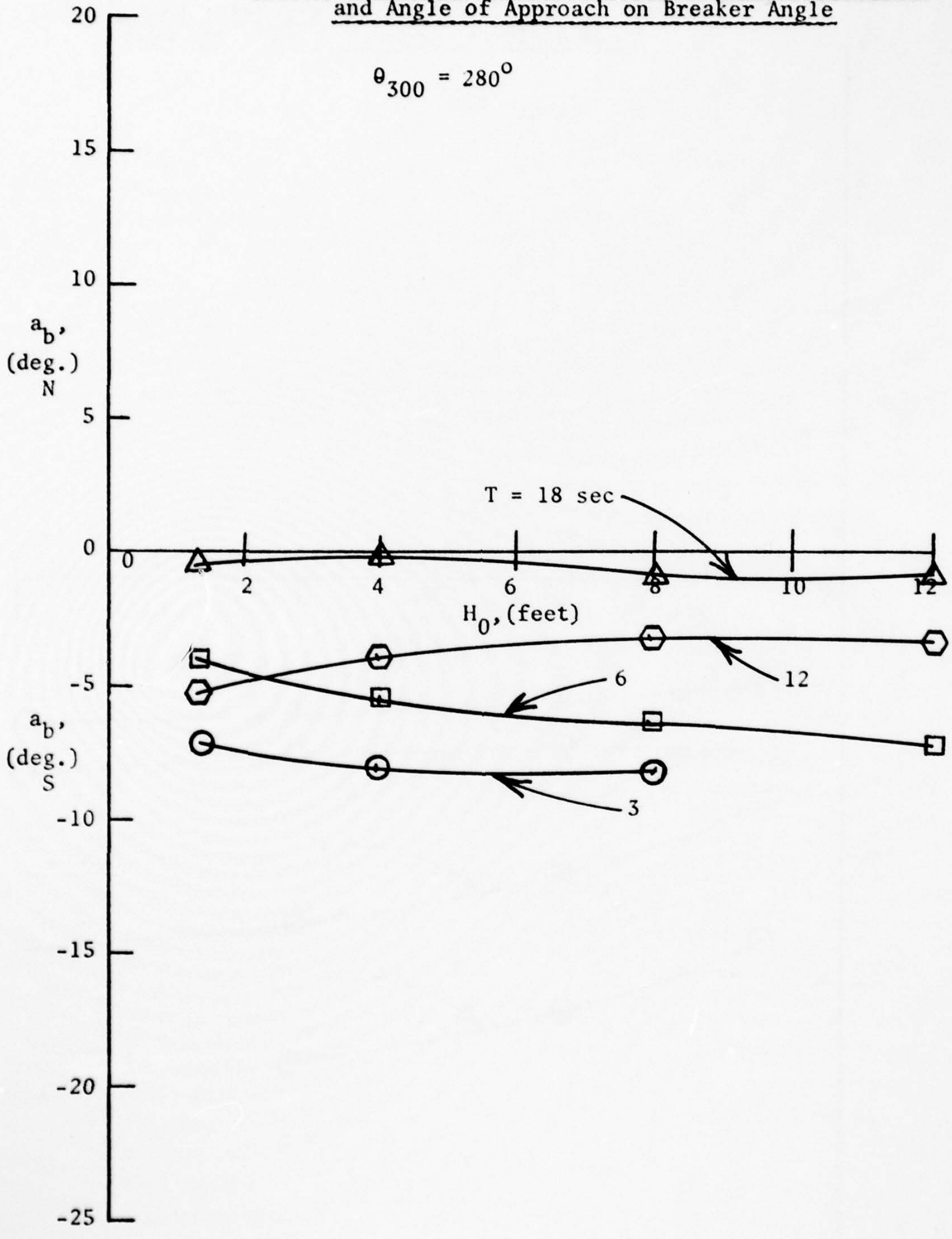
MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle



MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle



AD-A070 027 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 8/3
MISSION BAY, CALIFORNIA, LITTORAL COMPARTMENT STUDY.(U)
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UNCLASSIFIED WES-MP-HL-79-4 NL

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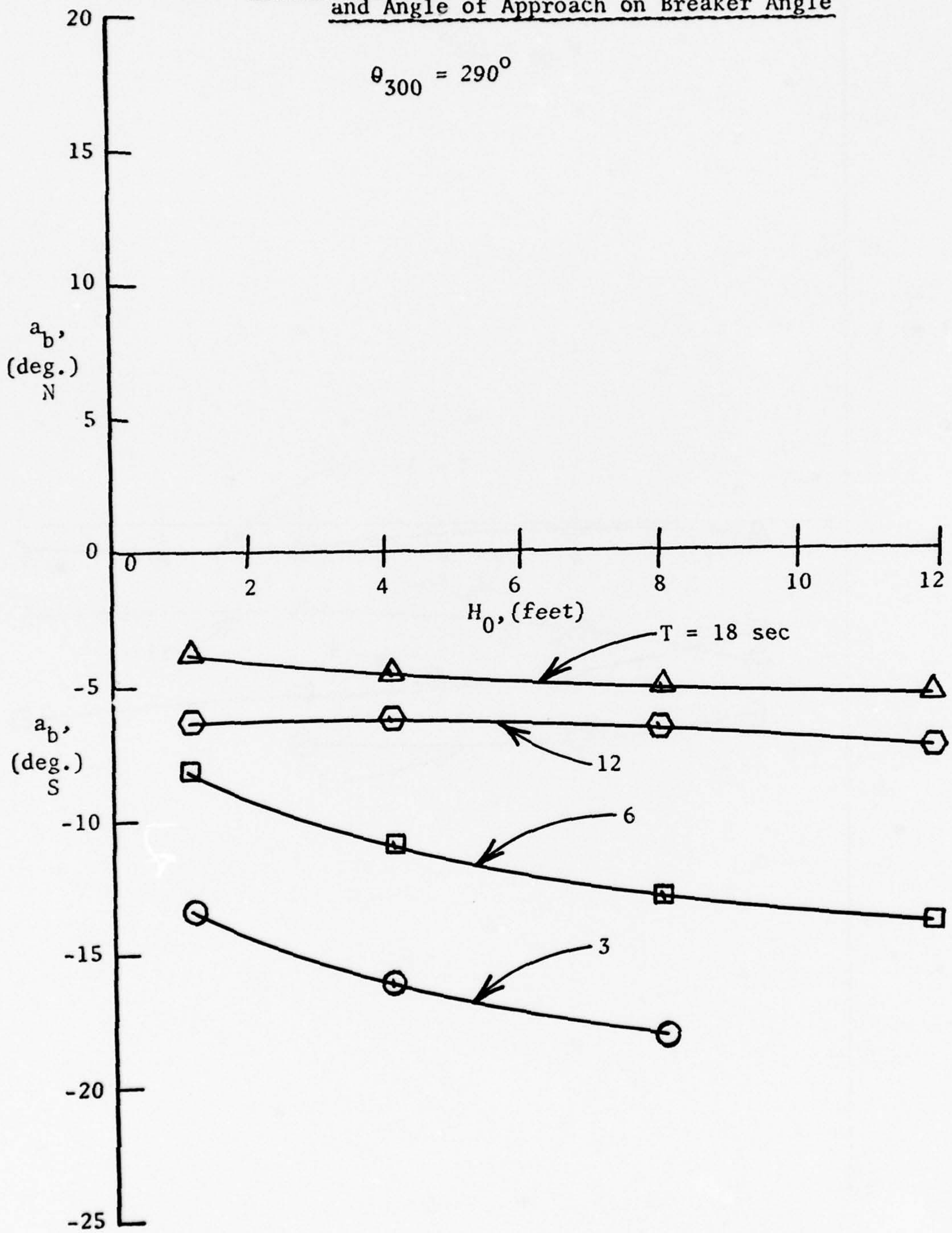
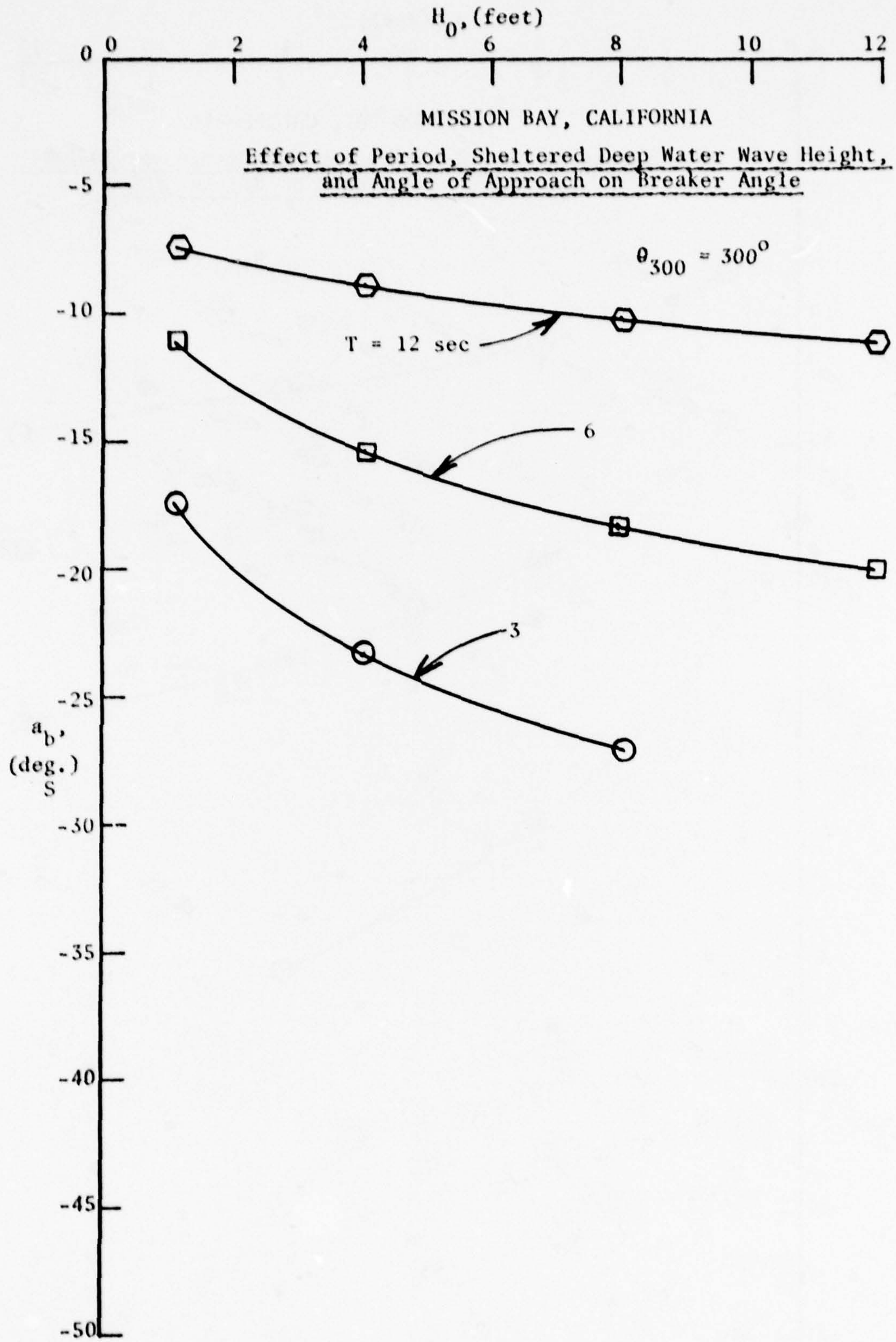
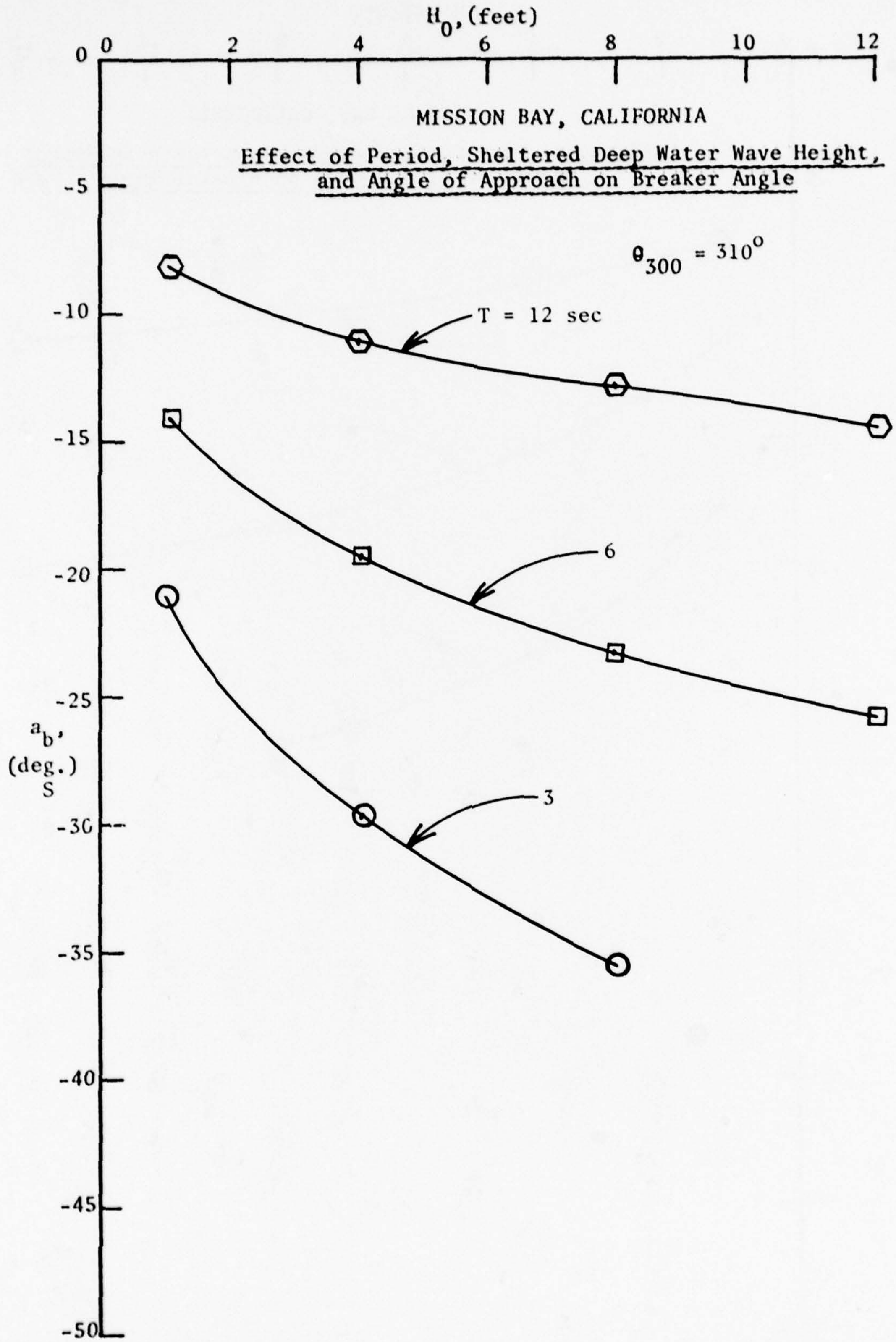
MISSION BAY, CALIFORNIA

Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle

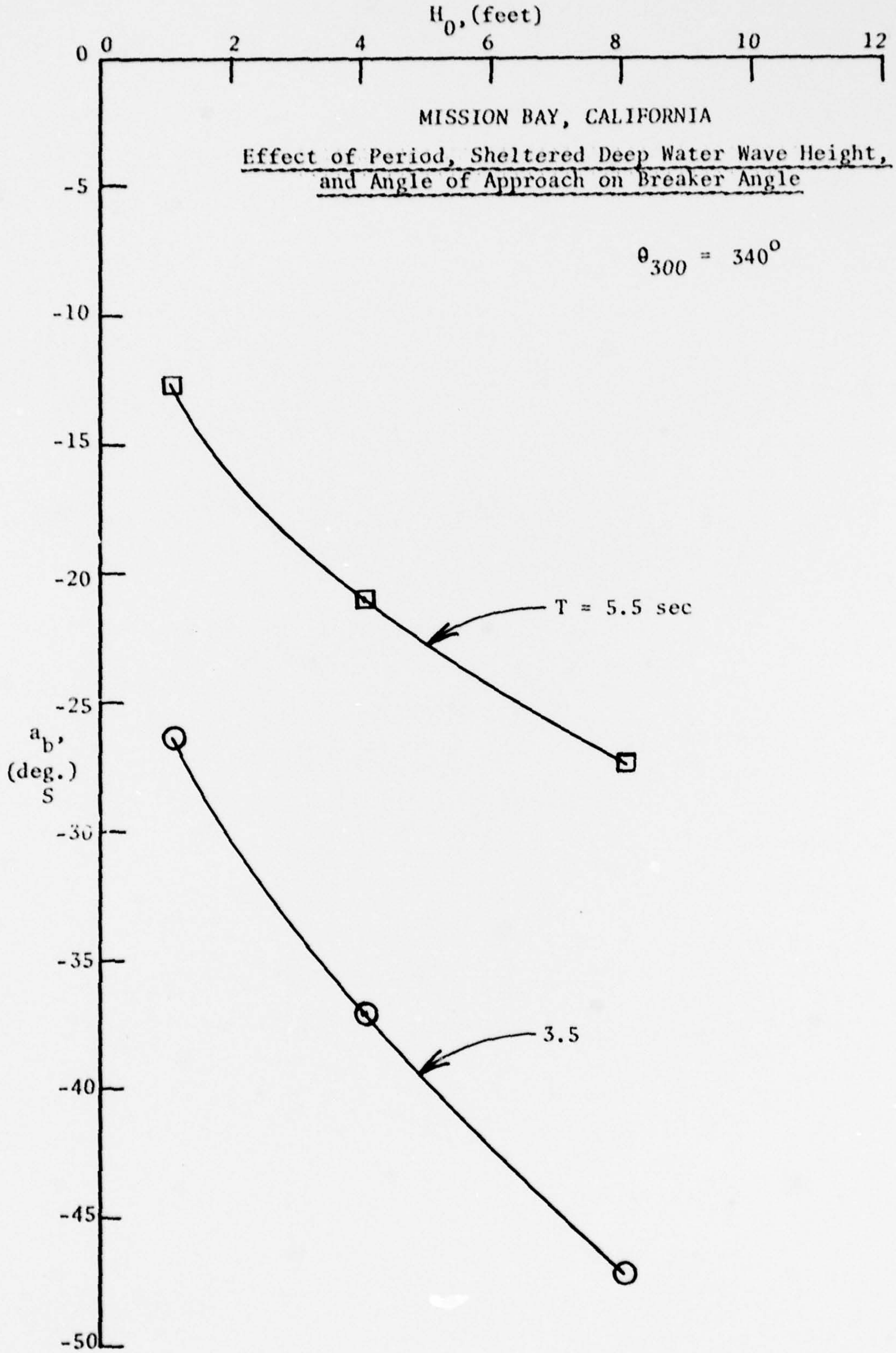




H_0, (feet)
0
2
4
6
8
10
12
MISSION BAY, CALIFORNIA
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle
θ_{300} = 300°
T = 12 sec
6
3
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
a_b, (deg.) S



H_0, (feet)
0
2
4
6
8
10
12
MISSION BAY, CALIFORNIA
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle
$\theta_{300} = 310^o$
T = 12 sec
6
3
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
a_b, (deg.) S



H_0, (feet)
0
2
4
6
8
10
12
MISSION BAY, CALIFORNIA
Effect of Period, Sheltered Deep Water Wave Height, and Angle of Approach on Breaker Angle
$\theta_{300} = 340^{\circ}$
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
a_b, (deg.) S
T = 5.5 sec
3.5

APPENDIX C: OPEN-OCEAN DEEP WATER WAVE STATISTICS

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 155° - 165°

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	2.1	1.2	1.0	0.1	
1.0-1.9	3.5	3.0	1.7	0.2	
2.0-2.9	1.2	1.1	0.5	0.1	
3.0-3.9	0.2	0.2	0.1	0.1	
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisers, January 1961

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 165^{o} - 175^{o}

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	1.1	1.1	0.5	0.1	
1.0-1.9	2.5	1.8	0.8	0.4	
2.0-2.9	0.3	0.5	0.1	0.1	
3.0-3.9	0.1				
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisers, January 1961

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 175° - 185°

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	1.8	1.0	0.4	0.2	
1.0-1.9	2.2	1.4	0.5	0.1	
2.0-2.9	0.4	0.1	0.1		
3.0-3.9			0.1		
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisers, January 1961

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 185^{o} - 195^{o}

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	0.4	0.3	0.2	0.1	
1.0-1.9	0.5	0.3	0.1		
2.0-2.9	0.1	0.1			
3.0-3.9					
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisers, January 1961

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 195° - 205°

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	1.2	0.5	0.1	0.2	
1.0-1.9	1.2	0.9	0.2	0.1	
2.0-2.9	0.5	0.7	0.2	0.1	
3.0-3.9		0.2	0.2	0.1	
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisers, January 1961

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 205^{o} - 215^{o}

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	1.1	0.5	0.1	0.1	
1.0-1.9	3.1	2.4	0.3		
2.0-2.9	0.3	0.5	0.2	0.1	
3.0-3.9	0.1	0.2	0.2	0.1	
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisers, January 1961

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 215^{o} - 225^{o}

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	0.7	0.1	0.1		
1.0-1.9	2.9	1.3	0.1	0.1	
2.0-2.9	2.1	2.1	0.5	0.1	
3.0-3.9	0.4	0.7	0.4	0.1	
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisers, January 1961

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = $225^{\circ} - 235^{\circ}$

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	0.7	0.4			
1.0-1.9	2.8	3.0	0.2	0.1	
2.0-2.9	2.0	1.3	0.2		
3.0-3.9	0.4	0.2	0.2	0.1	
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisers, January 1961

Frequency of Annual Occurrence of Open-Ocean Deep Water Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 125° - 135°

Significant Wave Height, feet	Wave Period, sec. 4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.05					
3.3-4.9	0.02					
4.9-6.6	0.01	0.01				
6.6-8.2		0.01				
8.2-9.8						
9.8-13.1						
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 135^{o} - 145^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.04					
3.3-4.9	0.03					
4.9-6.6		0.01				
6.6-8.2						
8.2-9.8						
9.8-13.1						
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 145° - 155°

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.06					
3.3-4.9	0.02					
4.9-6.6	0.01	0.01				
6.6-8.2						
8.2-9.8						
9.8-13.1						
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 155^{o} - 165^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.05					
3.3-4.9	0.04					
4.9-6.6	0.01	0.01				
6.6-8.2		0.01				
8.2-9.8						
9.8-13.1						
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 165^{o} - 175^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.07					
3.3-4.9	0.04					
4.9-6.6	0.01	0.01				
6.6-8.2		0.01				
8.2-9.8		0.01				
9.8-13.1			0.01			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water
Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 175°- 185°

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.10					
3.3-4.9	0.04					
4.9-6.6		0.01				
6.6-8.2		0.01				
8.2-9.8		0.01				
9.8-13.1			0.01			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 185^{o} - 195^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.07					
3.3-4.9	0.03					
4.9-6.6	0.01	0.04				
6.6-8.2		0.03				
8.2-9.8		0.01				
9.8-13.1			0.01			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 195° - 205°

Significant Wave Height, feet	Wave Period, sec. 4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.09					
3.3-4.9	0.06					
4.9-6.6	0.01	0.05				
6.6-8.2		0.03				
8.2-9.8			0.01			
9.8-13.1			0.01			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 205^{o} - 215^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.07					
3.3-4.9	0.05					
4.9-6.6	0.02					
6.6-8.2		0.06				
8.2-9.8		0.04				
9.8-13.1		0.01				
13.1-16.4			0.01			
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 215^{o} - 225^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.10					
3.3-4.9	0.06					
4.9-6.6	0.01	0.05				
6.6-8.2		0.04				
8.2-9.8						
9.8-13.1			0.01			
13.1-16.4			0.01			
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 225° - 235°

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.11					
3.3-4.9	0.06					
4.9-6.6		0.04				
6.6-8.2		0.04				
8.2-9.8		0.02				
9.8-13.1			0.01			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 235^{o} - 245^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.19					
3.3-4.9	0.07					
4.9-6.6	0.01	0.05				
6.6-8.2		0.04				
8.2-9.8		0.02				
9.8-13.1			0.01			
13.1-16.4			0.01			
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 245^{o} - 255^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.14					
3.3-4.9	0.11					
4.9-6.6	0.02	0.07				
6.6-8.2		0.04				
8.2-9.8		0.02				
9.8-13.1			0.02			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 255° - 265°

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.21					
3.3-4.9	0.18					
4.9-6.6	0.01	0.06				
6.6-8.2		0.03				
8.2-9.8		0.02				
9.8-13.1						
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 265^{o} - 275^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.36					
3.3-4.9	0.23					
4.9-6.6	0.01	0.07				
6.6-8.2		0.07				
8.2-9.8		0.04				
9.8-13.1			0.01			
13.1-16.4			0.01			
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 275^{o} - 285^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.59					
3.3-4.9	0.47					
4.9-6.6	0.05	0.25				
6.6-8.2		0.13				
8.2-9.8		0.04				
9.8-13.1			0.07			
13.1-16.4			0.01			
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 285^{o} - 295^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	1.08					
3.3-4.9	1.00					
4.9-6.6	0.12	0.60				
6.6-8.2		0.42				
8.2-9.8		0.24	0.02			
9.8-13.1			0.12			
13.1-16.4			0.02	0.01		
16.4-19.7						
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 295^{o} - 305^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	1.58					
3.3-4.9	2.30					
4.9-6.6	0.32	1.61				
6.6-8.2		1.31				
8.2-9.8		0.60	0.01			
9.8-13.1			0.30			
13.1-16.4			0.10	0.01		
16.4-19.7				0.01		
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 305^{o} - 315^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	2.63					
3.3-4.9	4.03					
4.9-6.6	0.53	2.85				
6.6-8.2		2.33				
8.2-9.8		1.19	0.01			
9.8-13.1			0.72			
13.1-16.4			0.11	0.01		
16.4-19.7				0.01		
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 315^{o} - 325^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	2.64					
3.3-4.9	4.08					
4.9-6.6	0.50	2.94				
6.6-8.2		2.10				
8.2-9.8		1.17	0.02			
9.8-13.1			0.74			
13.1-16.4			0.06	0.01		
16.4-19.7						
19.7-23.0				0.01		
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 325^{o} - 335^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	2.66					
3.3-4.9	3.29					
4.9-6.6	0.40	2.10				
6.6-8.2		1.50				
8.2-9.8		0.77	0.03			
9.8-13.1			0.42			
13.1-16.4			0.07			
16.4-19.7				0.01		
19.7-23.0						
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 335° - 345°

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	2.10					
3.3-4.9	2.13					
4.9-6.6	0.23	0.92				
6.6-8.2		0.64				
8.2-9.8		0.22				
9.8-13.1			0.14			
13.1-16.4			0.02	0.01		
16.4-19.7				0.01		
19.7-23.0				0.01		
23.0+						

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 115° - 125°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.01			0.01		
1.6-3.3		0.01					
3.3-4.9							
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 125° - 135°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6			0.01				
1.6-3.3		0.01					
3.3-4.9							
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 135^{o} - 145^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6				0.01			
1.6-3.3							
3.3-4.9							
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 145° - 155°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3		0.01					
3.3-4.9							
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 155^{o} - 165^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3			0.01				
3.3-4.9							
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 165^{o} - 175^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3		0.02	0.01				
3.3-4.9		0.01					
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 175^{o} - 185^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3				0.01			
3.3-4.9		0.01					
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 185^{o} - 195^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.02					
1.6-3.3	0.01	0.02	0.01		0.01		
3.3-4.9		0.01	0.01				
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 195^{o} - 205^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6			0.01				
1.6-3.3		0.09	0.01				
3.3-4.9		0.02					
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 205° - 215°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.01	0.01					
1.6-3.3	0.02	0.03					
3.3-4.9		0.01					
4.9-6.6			0.01				
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 215° - 225°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.01	0.01				
1.6-3.3		0.03	0.01				
3.3-4.9		0.01					
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 225° - 235°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.03					
1.6-3.3	0.01	0.07	0.02		0.01		
3.3-4.9		0.02	0.01				
4.9-6.6		0.01	0.01	0.01			
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 235^{o} - 245^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.01	0.02					
1.6-3.3	0.01	0.09	0.01				
3.3-4.9		0.04	0.01				
4.9-6.6		0.01					
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = $245^{\circ} - 255^{\circ}$

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.01		0.01				
1.6-3.3	0.01	0.07			0.01		
3.3-4.9		0.07			0.01	0.01	0.02
4.9-6.6			0.01	0.01			0.04
6.6-8.2				0.01			0.03
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 255° - 265°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.03	0.01	0.01			
1.6-3.3	0.02	0.03	0.02	0.03	0.01		0.01
3.3-4.9		0.03		0.01	0.01		0.01
4.9-6.6			0.01				0.16
6.6-8.2							0.02
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 265° - 275°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.04		0.01	0.04		
1.6-3.3		0.07	0.05	0.01	0.06	0.02	
3.3-4.9		0.02	0.04		0.02		0.01
4.9-6.6		0.01					0.02
6.6-8.2							0.01
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence
of
Open-Ocean Deep Water
Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 275° - 285°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.02		0.05	0.05	0.02	0.01
1.6-3.3		0.07	0.06	0.03	0.18	0.02	0.02
3.3-4.9		0.03	0.02	0.02	0.08	0.09	0.02
4.9-6.6			0.02		0.01		0.03
6.6-8.2							
8.2-9.8					0.01		
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 285° - 295°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.04	0.05	0.03	0.05	0.16	0.06	0.01
1.6-3.3	0.02	0.22	0.04	0.10	0.73	0.21	0.01
3.3-4.9		0.10	0.02	0.05	0.18	0.33	0.07
4.9-6.6		0.01	0.02		0.01	0.09	0.02
6.6-8.2			0.01		0.01	0.01	0.03
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 295^{o} - 305^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.01	0.21	0.12	0.04	0.44	0.16	0.01
1.6-3.3	0.10	0.99	0.07	0.32	2.14	0.63	0.07
3.3-4.9		0.23	0.07	0.11	0.45	0.93	0.26
4.9-6.6		0.01	0.01	0.01	0.03	0.11	0.15
6.6-8.2					0.02	0.01	0.01
8.2-9.8							0.01
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 305^{o} - 315^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.09	0.50	0.37	0.05	0.95	0.21	> 0.01
1.6-3.3	0.36	2.98	0.21	0.39	3.60	0.98	0.15
3.3-4.9		1.31	0.21	0.10	0.74	2.11	0.42
4.9-6.6		0.03	0.10	0.03	0.04	0.13	0.21
6.6-8.2			0.02	0.02	0.01	0.03	0.10
8.2-9.8							0.02
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 315° - 325°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.11	0.61	0.75	0.09	0.80	0.28	0.02
1.6-3.3	0.46	3.62	0.25	0.37	1.45	0.45	0.03
3.3-4.9	0.01	2.61	0.46	0.13	0.54	0.41	0.09
4.9-6.6		0.10	0.38	0.05	0.07	0.17	0.10
6.6-8.2			0.08	0.03		0.02	0.03
8.2-9.8			0.01	0.02			
9.8-13.1					0.01		
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 325° - 335°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.15	0.51	0.54	0.06	0.25	0.06	0.02
1.6-3.3	0.44	3.28	0.27	0.13	0.49	0.09	
3.3-4.9	0.03	2.70	0.41	0.07	0.18	0.15	0.01
4.9-6.6		0.07	0.42	0.04	0.03	0.04	0.01
6.6-8.2			0.06	0.05			0.02
8.2-9.8			0.01	0.02	0.01		
9.8-13.1					0.01		
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 335^{o} - 345^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.05	0.42	0.16	0.02	0.03	0.01	
1.6-3.3	0.28	2.48	0.28	0.08	0.05	0.02	
3.3-4.9		1.39	0.53	0.04	0.01	0.01	
4.9-6.6		0.02	0.13	0.07			
6.6-8.2			0.03	0.03			
8.2-9.8				0.03			
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

Frequency of Annual Occurrence

of

Open-Ocean Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Unsheltered Deep Water Approach Azimuth = 345^{o} - 355^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.03	0.10		0.01			
1.6-3.3	0.04	0.50	0.05		0.01		
3.3-4.9		0.15	0.10	0.01	0.01		
4.9-6.6			0.01	0.01			
6.6-8.2							
8.2-9.8					0.01		
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are a mid-point interpolation between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International Incorporated, February 1977. The wave height bands are 0.5 or 1.0 meter.

APPENDIX D: SHELTERED DEEP WATER WAVE STATISTICS

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 185^o - 195^o

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	9.20	4.20	2.70	0.33	
1.0-1.9	1.70	1.30	0.60	0.13	
2.0-2.9	0.10				
3.0-3.9					
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are based on Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisors, January 1961. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 195^{o} - 205^{o}

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	2.20	4.20	1.70	0.63	
1.0-1.9	3.10	2.30	0.63	0.05	
2.0-2.9	0.03	0.10	0.03		
3.0-3.9					
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are based on Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisors, January 1961. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 205° - 215°

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	2.30	0.50	0.23	0.25	
1.0-1.9	4.30	0.90	0.30	0.03	
2.0-2.9	0.80	0.70	0.20	0.10	
3.0-3.9	0.10	0.20	0.20	0.10	
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are based on Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisors, January 1961. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 215° - 225°

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	0.70	0.60	0.05	0.03	
1.0-1.9	2.90	3.70	0.40	0.10	
2.0-2.9	2.10	2.60	0.70	0.05	
3.0-3.9	0.40	0.90	0.60	0.05	
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are based on Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisors, January 1961. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Southern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 225° - 235°

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	0.70	0.40			
1.0-1.9	2.80	3.00	0.20	0.03	
2.0-2.9	2.00	1.30	0.20		
3.0-3.9	0.40	0.20	0.20	0.03	
4.0-4.9					
5.0-5.9					
6.0-6.9					

These data are based on Station A data in the report "A Statistical Survey of Ocean Wave Characteristics in Southern California Waters", Marine Advisors, January 1961. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 165^{o} - 175^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.01	0.01				
1.6-3.3							
3.3-4.9							
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 175° - 185°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.01		0.01			
1.6-3.3							
3.3-4.9							
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 185^{o} - 195^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3		0.02	0.01				
3.3-4.9							
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 195° - 205°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.02					
1.6-3.3	0.01	0.02	0.01	0.01	0.01		
3.3-4.9		0.02	0.01				
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 205^o - 215^o

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.01	0.01	0.01				
1.6-3.3	0.02	0.12	0.01				
3.3-4.9		0.03					
4.9-6.6			0.01				
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 215^{o} - 225^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.01	0.01				
1.6-3.3		0.03	0.01				
3.3-4.9		0.01					
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = $225^{\circ} - 235^{\circ}$

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.03					
1.6-3.3	0.01	0.01	0.02		0.01		
3.3-4.9		0.02	0.02				
4.9-6.6		0.01	0.01	0.01			
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 235^{o} - 245^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.01	0.02	0.01				
1.6-3.3	0.01	0.16			0.01		0.01
3.3-4.9		0.11			0.01	0.01	0.19
4.9-6.6		0.01	0.01	0.01			0.06
6.6-8.2				0.01			0.03
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 245^{o} - 255^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.01	0.03	0.01	0.02	0.04	0.02	0.01
1.6-3.3	0.03	0.03	0.02	0.04	0.09	0.12	0.05
3.3-4.9		0.03	0.01	0.01	0.01		0.05
4.9-6.6							0.01
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 255° - 265°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.06		0.10	0.16	0.85	0.08
1.6-3.3		0.17	0.09	0.21	0.92	1.59	0.52
3.3-4.9		0.03	0.02		0.01	0.10	0.06
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 265° - 275°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.04	0.05	0.15	0.37	2.58	3.30	0.89
1.6-3.3	0.02	0.32	0.21	0.12	0.48	0.17	0.02
3.3-4.9		0.01	0.03		0.02		
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Northern Hemisphere Swell Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 275° - 285°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.45	3.69	0.58	0.44	5.29		
1.6-3.3	0.10	2.57	0.33	0.15	0.05		
3.3-4.9		0.01					
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence
of
Sheltered Deep Water
Northern Hemisphere Swell Characteristics
(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 290° - 295°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	1.16	8.02	2.22	0.84	3.74	1.65	0.33
1.6-3.3	0.03	5.48	1.42	0.21	0.10		
3.3-4.9			0.01				
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							
16.4-19.7							
19.7-23.0							
23.0+							

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 195^{o} - 205^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.17					
3.3-4.9	0.07	0.04				
4.9-6.6		0.04				
6.6-8.2		0.01	0.01			
8.2-9.8			0.01			
9.8-13.1						
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 205° - 215°

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.17					
3.3-4.9	0.11					
4.9-6.6	0.02	0.10				
6.6-8.2		0.06				
8.2-9.8		0.01	0.01			
9.8-13.1			0.01			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 215° - 225°

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.10					
3.3-4.9	0.06					
4.9-6.6	0.01	0.04				
6.6-8.2		0.03				
8.2-9.8						
9.8-13.1			0.01			
13.1-16.4			0.01			
16.4-19.7						
19.7-23.0						
23.0+						

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 225^{o} - 235^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.11					
3.3-4.9	0.06					
4.9-6.6		0.03				
6.6-8.2		0.04				
8.2-9.8		0.02				
9.8-13.1			0.01			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 235^{o} - 245^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.19					
3.3-4.9	0.07					
4.9-6.6	0.01	0.05				
6.6-8.2		0.04				
8.2-9.8		0.02	0.01			
9.8-13.1			0.01			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 245^{o} - 255^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.35					
3.3-4.9	0.30					
4.9-6.6	0.02	0.13				
6.6-8.2		0.07				
8.2-9.8		0.04				
9.8-13.1			0.02			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 255^{o} - 265^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.36					
3.3-4.9	0.23					
4.9-6.6	0.01	0.07				
6.6-8.2		0.07				
8.2-9.8		0.04	0.01			
9.8-13.1			0.01			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 265^{o} - 275^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	0.59					
3.3-4.9	0.52	0.25				
4.9-6.6		0.13				
6.6-8.2		0.04				
8.2-9.8			0.07			
9.8-13.1			0.01			
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Sheltered Deep Water

Sea Characteristics

(Frequency in Percent of Year)

Sheltered Deep Water Approach Azimuth = 275^{o} - 285^{o}

Significant Wave Height, feet	Wave Period, sec.					
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9
0.0-1.6						
1.6-3.3	2.09					
3.3-4.9	0.12	0.60				
4.9-6.6		0.42				
6.6-8.2		0.24	0.14			
8.2-9.8			0.02	0.01		
9.8-13.1						
13.1-16.4						
16.4-19.7						
19.7-23.0						
23.0+						

These data are based on mid-point interpolations between Stations 5 and 6 in the report "Wave Statistics for Six Deep-Water Stations Along the California Coast", Meteorology International, Incorporated, February 1977. Adjusted for island sheltering by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Sheltered Deep Water Depth = 300 ft. The wave height bands are 0.5 and 1.0 meter.

MISSION BAY, CALIFORNIA

<u>Frequency of Annual Occurrence</u>

<u>of</u>

<u>Locally Generated Sea Characteristics</u>

(Frequency in Percent of Year)

Deep Water Approach Azimuth = 180° - 210°

Significant Wave Height, feet	Wind Velocity (knots) and Wave Period (sec.)			
	10-15 knots 3.5 sec	15-20 knots 5.0 sec	20-25 knots 5.5 sec	25+ knots 6.0 sec
3.0	0.69			
5.0		0.30		
6.5			0.12	
8.0				0.11

These data were developed from wind frequencies which were obtained from Synoptic Shipboard Meteorological Observations (SSMO) data tapes. Water depth = 300 ft.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Locally Generated Sea Characteristics

(Frequency in Percent of Year)

Deep Water Approach Azimuth = 210^{o} - 240^{o}

Significant Wave Height, feet	Wind Velocity (knots) and Wave Period (sec.)			
	10-15 knots 3.5 sec	15-20 knots 5.0 sec	20-25 knots 5.5 sec	25+ knots 6.0 sec
3.0	0.99			
5.0		0.17		
6.5			0.10	
8.0				0.02

These data were developed from wind frequencies which were obtained from Synoptic Shipboard Meteorological Observations (SSMO) data tapes. Water depth = 300 ft.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence
of
Locally Generated Sea Characteristics
(Frequency in Percent of Year)

Deep Water Approach Azimuth = $240^{\circ} - 270^{\circ}$

Significant Wave Height, feet	Wind Velocity (knots) and Wave Period (sec.)			
	10-15 knots 3.5 sec	15-20 knots 5.0 sec	20-25 knots 5.5 sec	25+ knots 6.0 sec
3.0	4.46			
5.0		1.32		
6.5			0.41	
8.0				0.09

These data were developed from wind frequencies which were obtained from Synoptic Shipboard Meteorological Observations (SSMO) data tapes. Water depth = 300 ft.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Locally Generated Sea Characteristics

(Frequency in Percent of Year)

Deep Water Approach Azimuth = 270° - 300°

Significant Wave Height, feet	Wind Velocity (knots) and Wave Period (sec.)			
	10-15 knots 3.5 sec	15-20 knots 5.0 sec	20-25 knots 5.5 sec	25+ knots 6.0 sec
3.0	4.56			
5.0		1.40		
6.5			0.47	
8.0				0.21

These data were developed from wind frequencies which were obtained from Synoptic Shipboard Meteorological Observations (SSMO) data tapes. Water depth = 300 ft.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Locally Generated Sea Characteristics

(Frequency in Percent of Year)

Deep Water Approach Azimuth = 300^o - 330^o

Significant Wave Height, feet	Wind Velocity (knots) and Wave Period (sec.)			
	10-15 knots 4.0 sec	15-20 knots 5.0 sec	20-25 knots 6.0 sec	25+ knots 7.0 sec
3.5	3.47			
5.5		1.18		
7.5			0.44	
9.5				0.08

These data were developed from wind frequencies which were obtained from Synoptic Shipboard Meteorological Observations (SSMO) data tapes. Water depth = 300 ft.

MISSION BAY, CALIFORNIA

Frequency of Annual Occurrence

of

Locally Generated Sea Characteristics

(Frequency in Percent of Year)

Deep Water Approach Azimuth = 330^{o} - 350^{o}

Significant Wave Height, feet	Wind Velocity (knots) and Wave Period (sec.)			
	10-15 knots 3.5 sec	15-20 knots 4.5 sec	20-25 knots 5.0 sec	25+ knots 5.5 sec
2.5	1.32			
4.0		0.23		
5.5			0.12	
6.5				0.01

These data were developed from wind frequencies which were obtained from Synoptic Shipboard Meteorological Observations (SSMO) data tapes. Water depth = 300 ft.

APPENDIX E: ANNUAL LONGSHORE TRANSPORT

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Southern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 185^{o} - 195^{o}

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	9.20 0.9 +3.0 +1779	4.20 1.0 +3.5 +1232	2.70 1.1 +4.0 +1148	0.33 1.2 +4.5 +193	
1.0-1.9	1.70 1.5 +5.3 +2075	1.30 1.8 +5.8 +2736	0.60 2.1 +6.2 +1982	0.13 2.3 +6.6 +551	
2.0-2.9	0.10 2.3 +7.7 +513				
3.0-3.9					

Legend

Time (Percent of Year).
Breaker Height. H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Southern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth $= 195^{\circ} - 205^{\circ}$

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	2.2 0.9 +3.6 +510	4.2 1.1 +3.3 +1475	1.7 1.2 +2.9 +652	0.63 1.3 +2.5 +848	
1.0-1.9	3.1 2.1 +5.8 +9590	2.3 2.3 +5.4 +8324	0.63 2.5 +4.9 +2530	0.05 2.7 +4.5 +226	
2.0-2.9	0.03 3.0 +7.8 +252	0.10 3.4 +7.2 +1276	0.03 3.7 +6.8 +373		
3.0-3.9					

Legend

Time (Percent of Year).
Breaker Height. H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

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Annual Longshore Transport

Southern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 205^o - 215^o

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	2.3 1.2 +4.3 +1306	0.5 1.3 +2.8 +226	0.23 1.4 +1.5 +66	0.25 1.5 +0.5 +29	
1.0-1.9	4.30 2.4 +6.2 +19837	0.90 2.6 +5.0 +4101	0.30 2.8 +3.8 +1253	0.03 3.0 +2.8 +92	
2.0-2.9	0.80 3.5 +8.3 +12610	0.70 3.8 +7.1 +11637	0.20 4.1 +5.8 +3295	0.10 4.4 +5.0 +1698	
3.0-3.9	0.10 4.5 +10.1 +3571	0.20 4.9 +9.0 +7908	0.20 5.3 +8.0 +8583	0.10 5.7 +7.1 +4581	

Legend

Time (Percent of Year).
Breaker Height. H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Southern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 215° - 225°

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	0.70 1.3 +3.3 +373	0.60 1.4 +2.7 +315	0.05 1.5 +2.0 +23	0.03 1.6 +1.3 +9	
1.0-1.9	2.90 2.5 +5.3 +12692	3.70 2.7 +4.6 +17060	0.40 2.9 +4.0 +1919	0.10 3.1 +3.4 +482	
2.0-2.9	2.10 3.7 +7.2 +33109	2.60 4.0 +6.5 +45059	0.70 4.3 +6.0 +13434	0.05 4.6 +5.3 +1005	
3.0-3.9	0.40 4.8 +9.0 +15021	0.90 5.2 +8.3 +38169	0.60 5.6 +7.6 +28106	0.05 6.0 +7.1 +2604	

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Southern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 225° - 235°

Significant Wave Height, feet	Wave Period, sec.				
	12-13.9	14-15.9	16-17.9	18-19.9	20+
0.0-0.9	0.70 1.3 +2.5 +283	0.40 1.4 +2.4 +187			
1.0-1.9	2.80 2.6 +4.5 +11495	3.00 2.8 +4.2 +13841	0.20 3.0 +4.0 +1045	0.03 3.1 +3.7 +131	
2.0-2.9	2.00 3.8 +6.3 +29566	1.30 4.1 +6.0 +22149	0.20 4.3 +5.7 +3649		
3.0-3.9	0.40 4.9 +7.7 +13592	0.20 5.3 +7.4 +7954	0.20 5.7 +7.0 +9036	0.03 6.1 +6.7 +1282	

Legend

Time (Percent of Year).
Breaker Height. H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 165^{o} - 175^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.01 0.5 +6.6 +1	0.01 0.6 +5.3 +1				
1.6-3.3							
3.3-4.9							
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 175^{o} - 185^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.01 0.6 +6.7 +1		0.01 0.7 +3.5 +1			
1.6-3.3							
3.3-4.9							
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 185^o - 195^o

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3		0.02 1.7 +11.3 +80	0.01 1.9 +10.0 +47				
3.3-4.9							
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 195^{o} - 205^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.02 0.9 +8.3 +9					
1.6-3.3	0.01 1.9 +18.5 +41	0.02 2.1 +12.7 +113	0.01 2.5 +11.0 +51	0.01 2.8 +9.0 +56	0.01 3.1 +7.8 +63		
3.3-4.9		0.02 3.3 +16.7 +451	0.01 3.6 +14.5 +164				
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 205° - 215°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.01 0.9 +14.0 +5	0.01 1.1 +9.8 +6	0.01 1.3 +8.0 +7				
1.6-3.3	0.02 2.1 +20.7 +177	0.12 2.4 +14.5 +1253	0.01 2.8 +12.3 +151				
3.3-4.9		0.03 3.7 +18.3 +1299					
4.9-6.6			0.01 5.5 +18.0 +575				
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 215° - 225°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.01 1.2 +8.4 +6	0.01 1.4 +6.8 +8				
1.6-3.3		0.03 2.6 +12.7 +322	0.01 2.9 +10.7 +144				
3.3-4.9		0.01 4.0 +16.0 +468					
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 225^{o} - 235^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.03 1.2 +6.7 +25					
1.6-3.3	0.01 2.5 +14.5 +132	0.01 2.8 +10.7 +858	0.02 3.1 +9.0 +288		0.01 3.8 +6.3 +85		
3.3-4.9		0.02 4.3 +13.7 +730	0.02 4.7 +11.7 +1049				
4.9-6.6		0.01 5.7 +15.7 +1115	0.01 6.3 +13.5 +624	0.01 7.0 +11.3 +687			
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 235^{o} - 245^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.01 1.1 +6.7 +8	0.02 1.3 +4.8 +13	0.01 1.4 +3.0 +7				
1.6-3.3	0.01 2.5 +11.0 +51	0.16 2.9 +7.4 +1413			0.01 3.9 +3.2 +46		0.01 4.5 +3.6 +74
3.3-4.9		0.11 4.4 +10.0 +3640			0.01 5.9 +5.2 +211	0.01 6.4 +5.5 +273	0.19 6.8 +5.7 +10848
4.9-6.6		0.01 6.0 +11.8 +487	0.01 6.6 +9.9 +523	0.01 7.2 +8.0 +529			0.06 8.8 +6.8 +8196
6.6-8.2				0.01 8.8 +8.3 +905			0.03 10.8 +7.8 +8531
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 245^{o} - 255^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.01	0.03	0.01	0.02	0.04	0.02	0.01
	1.1	1.3	1.5	1.6	1.7	1.9	2.0
	+5.0	+3.0	+1.0	-1.0	-1.8	-1.5	-.13
	+3	+14	+1	-6	-23	-14	-4
1.6-3.3	0.03	0.03	0.02	0.04	0.09	0.12	0.05
	2.7	2.9	3.3	3.7	4.0	4.4	4.7
	+7.5	+4.7	+3.0	+1.2	+0.5	+1.2	+1.8
	+214	+194	+114	+106	+123	+493	+373
3.3-4.9		0.03	0.01	0.01	0.01		0.05
		4.6	5.0	5.5	6.0		7.0
		+6.3	+4.5	+2.7	+2.0		+3.8
		+683	+121	+92	+85		+2129
4.9-6.6							0.01
							9.2
							+4.5
							+1108
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 255° - 265°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6		0.06 1.4 +1.3 +16		0.10 1.7 -2.5 -77	0.16 1.9 -2.5 -167	0.85 2.0 -0.8 -322	0.08 2.2 +1.0 +48
1.6-3.3		0.17 3.1 +2.2 +519	0.09 3.6 +0.7 +124	0.21 4.0 -0.7 -399	0.92 4.3 -0.7 -2067	1.59 4.6 +0.7 +4237	0.52 4.9 +2.3 +5291
3.3-4.9		0.03 4.9 +2.9 +370	0.02 5.5 +1.7 +232		0.01 6.5 +0.8 +83	0.10 6.9 +2.5 +2706	0.06 7.4 +3.5 +2754
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 265^{o} - 275^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.04 1.3 -0.4 -3	0.05 1.5 -1.0 -12	0.15 1.7 -2.5 -118	0.37 1.9 -4.0 -611	2.58 2.0 -3.5 -4279	3.30 2.2 -1.0 -1991	0.89 2.3 +2.0 +1204
1.6-3.3	0.02 3.0 -0.4 -9	0.32 3.4 -0.8 -452	0.21 3.8 -1.5 -752	0.12 4.3 -2.5 -968	0.48 4.7 -2.0 -3871	0.17 4.9 +0.4 +297	0.02 5.1 +2.7 +305
3.3-4.9		0.01 5.2 -0.7 -21	0.03 5.8 -1.0 -234		0.02 7.0 -1.3 -324		
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 275° - 285°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	0.45 1.3 -5.5 -401	3.69 1.5 -4.7 -3998	0.58 1.7 -5.0 -912	0.44 1.8 -5.5 -881	5.29 1.9 -4.8 -10565		
1.6-3.3	0.10 2.9 -6.2 -721	2.57 3.2 -5.2 -20434	0.33 3.6 -4.8 -3281	0.15 4.0 -4.6 -1835	0.05 4.3 -4.2 -618		
3.3-4.9		0.01 4.9 -5.7 -145					
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Northern Hemisphere Swell Characteristics

Sheltered Deep Water Approach Azimuth = 285^o - 295^o

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6	1.16 1.2 -10.0 -1511	8.02 1.4 -8.1 -12485	2.22 1.5 -7.4 -3758	0.84 1.6 -6.8 -1544	3.74 1.7 -6.2 -7288	1.65 1.8 -5.3 -3176	0.33 1.9 -4.4 -599
1.6-3.3	0.03 2.8 -12.0 -442	5.48 3.1 -9.5 -72716	1.42 3.4 -8.2 -20504	0.21 3.7 -7.0 -3163	0.10 3.9 -6.2 -1512		
3.3-4.9			0.01 5.1 -9.0 -250				
4.9-6.6							
6.6-8.2							
8.2-9.8							
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Sea Characteristics

Sheltered Deep Water Approach Azimuth = 195° - 205°

Significant Wave Height, feet	Wave Period, sec. 4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3	0.17 1.9 +18.5 +1198						
3.3-4.9	0.07 3.0 +24.0 +1917	0.04 3.3 +16.7 +1202					
4.9-6.6		0.04 4.3 +19.8 +2360					
6.6-8.2		0.01 5.3 +22.0 +1239	0.01 5.9 +19.0 +1436				
8.2-9.8			0.01 6.8 +20.7 +1100				
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Sea Characteristics

Sheltered Deep Water Approach Azimuth = 205° - 215°

Significant Wave Height, feet	Wave Period, sec. 4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3	0.17 2.1 +20.7 +1691						
3.3-4.9	0.11 3.4 +26.0 +4634						
4.9-6.6	0.02 4.5 +29.5 +2032	0.10 4.9 +21.1 +8864					
6.6-8.2		0.06 6.3 +23.1 +9918					
8.2-9.8		0.01 7.3 +25.0 +3043	0.01 8.0 +21.8 +3444				
9.8-13.1			0.01 9.8 +23.5 +6066				
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Sea Characteristics

Sheltered Deep Water Approach Azimuth = 215^{o} - 225^{o}

Significant Wave Height, feet	Wave Period, sec. 4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3	0.10 2.3 +17.5 +1142						
3.3-4.9	0.06 3.6 +22.5 +2398						
4.9-6.6	0.01 4.8 +25.5 +541	0.04 5.3 +18.2 +4235					
6.6-8.2		0.03 6.6 +19.9 +5928					
8.2-9.8							
9.8-13.1			0.01 10.6 +20.5 +3310				
13.1-16.4			0.01 12.4 +22.7 +5318				

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Sea Characteristics

Sheltered Deep Water Approach Azimuth = 225^{o} - 235^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3	0.11 2.5 +14.5 +1322						
3.3-4.9	0.06 3.8 +19.0 +2629						
4.9-6.6		0.03 5.7 +15.7 +3345					
6.6-8.2		0.04 7.0 +17.1 +7036					
8.2-9.8		0.02 8.4 +18.5 +5093					
9.8-13.1			0.01 11.3 +17.5 +3396				
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Sea Characteristics

Sheltered Deep Water Approach Azimuth = 235^{o} - 245^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3	0.19 2.5 +11.0 +1685						
3.3-4.9	0.07 4.0 +14.0 +2694						
4.9-6.6	0.01 5.4 +16.2 +501	0.05 6.0 +11.8 +4383					
6.6-8.2		0.04 7.3 +12.8 +6007					
8.2-9.8		0.02 8.6 +14.2 +4269	0.01 9.4 +11.8 +1496				
9.8-13.1			0.01 11.7 +13.0 +2831				
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Sea Characteristics

Sheltered Deep Water Approach Azimuth = 245^o - 255^o

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3	0.35 2.7 +7.5 +2609						
3.3-4.9	0.30 4.1 +9.5 +7948						
4.9-6.6	0.02 5.6 +11.0 +1534	0.13 6.1 +7.8 +7500					
6.6-8.2		0.07 7.6 +8.7 +7882					
8.2-9.8		0.04 9.0 +9.7 +7793					
9.8-13.1			0.02 12.2 +8.5 +8386				
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Sea Characteristics

Sheltered Deep Water Approach Azimuth = 255° - 265°

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3	0.36 2.8 +3.5 +1367						
3.3-4.9	0.23 4.3 +4.5 +3392						
4.9-6.6	0.01 5.8 +5.5 +426	0.07 6.5 +3.6 +2421					
6.6-8.2		0.07 8.1 +4.1 +4408					
8.2-9.8		0.04 9.5 +4.5 +4202	0.01 10.4 +3.5 +586				
9.8-13.1			0.01 12.7 +4.3 +1186				
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Sea Characteristics

Sheltered Deep Water Approach Azimuth = 265^{o} - 275^{o}

Significant Wave Height, feet	Wave Period, sec. 4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3	0.59 3.0 -0.4 -309						
3.3-4.9	0.52 4.5 -0.2 -376	0.25 5.2 -0.7 -894					
4.9-6.6		0.13 6.8 -0.7 -894					
6.6-8.2		0.04 8.4 -0.5 -345					
8.2-9.8			0.07 11.1 -0.3 -712				
9.8-13.1			0.01 13.5 -0.2 -64				
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Sea Characteristics

Sheltered Deep Water Approach Azimuth = 275^{o} - 285^{o}

Significant Wave Height, feet	Wave Period, sec.						
	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	16+
0.0-1.6							
1.6-3.3	2.09 2.9 -6.2 -15440						
3.3-4.9	0.12 4.4 -6.7 -2726	0.60 4.8 -5.7 -14313					
4.9-6.6		0.42 6.3 -6.0 -20856					
6.6-8.2		0.24 8.2 -6.3 -24333	0.14 8.9 -5.1 -13853				
8.2-9.8			0.02 10.4 -5.2 -2606	0.01 11.2 -4.0 -806			
9.8-13.1							
13.1-16.4							

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Locally Generated Sea Characteristics

Sheltered Deep Water Approach Azimuth = 180° - 210°

Significant Wave Height, feet	Wave Period 3.5 sec	5.0 sec	5.5 sec	6.0 sec
3.0	0.69 2.0 +27.5 +7642			
5.0		0.30 3.2 +25.5 +10213		
6.5			0.12 4.1 +25.3 +7725	
8.0				0.11 5.0 +23.5 +10827

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Locally Generated Sea Characteristics

Sheltered Deep Water Approach Azimuth = 210° - 240°

Significant Wave Height, feet	Wave Period			
	3.5 sec	5.0 sec	5.5 sec	6.0 sec
3.0	0.99 2.7 +23.0 +20620			
5.0		0.17 4.5 +22.0 +11997		
6.5			0.10 5.7 +21.8 +12235	
8.0				0.02 6.9 +20.5 +3358

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Locally Generated Sea Characteristics

Sheltered Deep Water Approach Azimuth = 240^{o} - 270^{o}

Significant Wave Height, feet	Wave Period 3.5 sec	5.0 sec	5.5 sec	6.0 sec
3.0	4.46 3.0 +8.0 +46126			
5.0		1.32 5.1 +8.0 +51257		
6.5			0.41 6.4 +8.0 +28124	
8.0				0.09 7.9 +7.5 +9837

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Locally Generated Sea Characteristics

Sheltered Deep Water Approach Azimuth = 270° - 300°

Significant Wave Height, feet	Wave Period			
	3.5 sec	5.0 sec	5.5 sec	6.0 sec
3.0	4.56 3.0 -11.5 -66837			
5.0		1.40 5.1 -10.5 -70746		
6.5			0.47 6.5 -10.0 -41509	
8.0				0.21 8.1 -10.0 -31827

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Locally Generated Sea Characteristics

Sheltered Deep Water Approach Azimuth = 300° - 330°

Significant Wave Height, feet	Wave Period			
	4.0 sec	5.0 sec	6.0 sec	7.0 sec
3.5	3.47 3.2 -26.5 -122038			
5.5		1.18 5.1 -25.5 -129497		
7.5			0.44 6.8 -22.7 -91636	
9.5				0.08 8.5 -21.0 -27712

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

MISSION BAY, CALIFORNIA

Annual Longshore Transport

Locally Generated Sea Characteristics

Sheltered Deep Water Approach Azimuth = 330° - 350°

Significant Wave Height, feet	Wave Period			
	3.5 sec	4.5 sec	5.0 sec	5.5 sec
2.5	1.32 1.8 -32.4 -12499			
4.0		0.23 2.7 -29.3 -5662		
5.5			0.12 3.6 -28.5 -5958	
6.5				0.01 4.1 -25.4 -635

Legend

Time (Percent of Year).
Breaker Height, H_b.
Breaker Angle, a_b.
Longshore Transport, cu yds/year.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Hales, Lyndell Z

Mission Bay, California, littoral compartment study / by Lyndell Z. Hales. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1979.

60, [159] p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; HL-79-4)

Prepared for U. S. Army Engineer District, Los Angeles, Los Angeles, Calif.

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